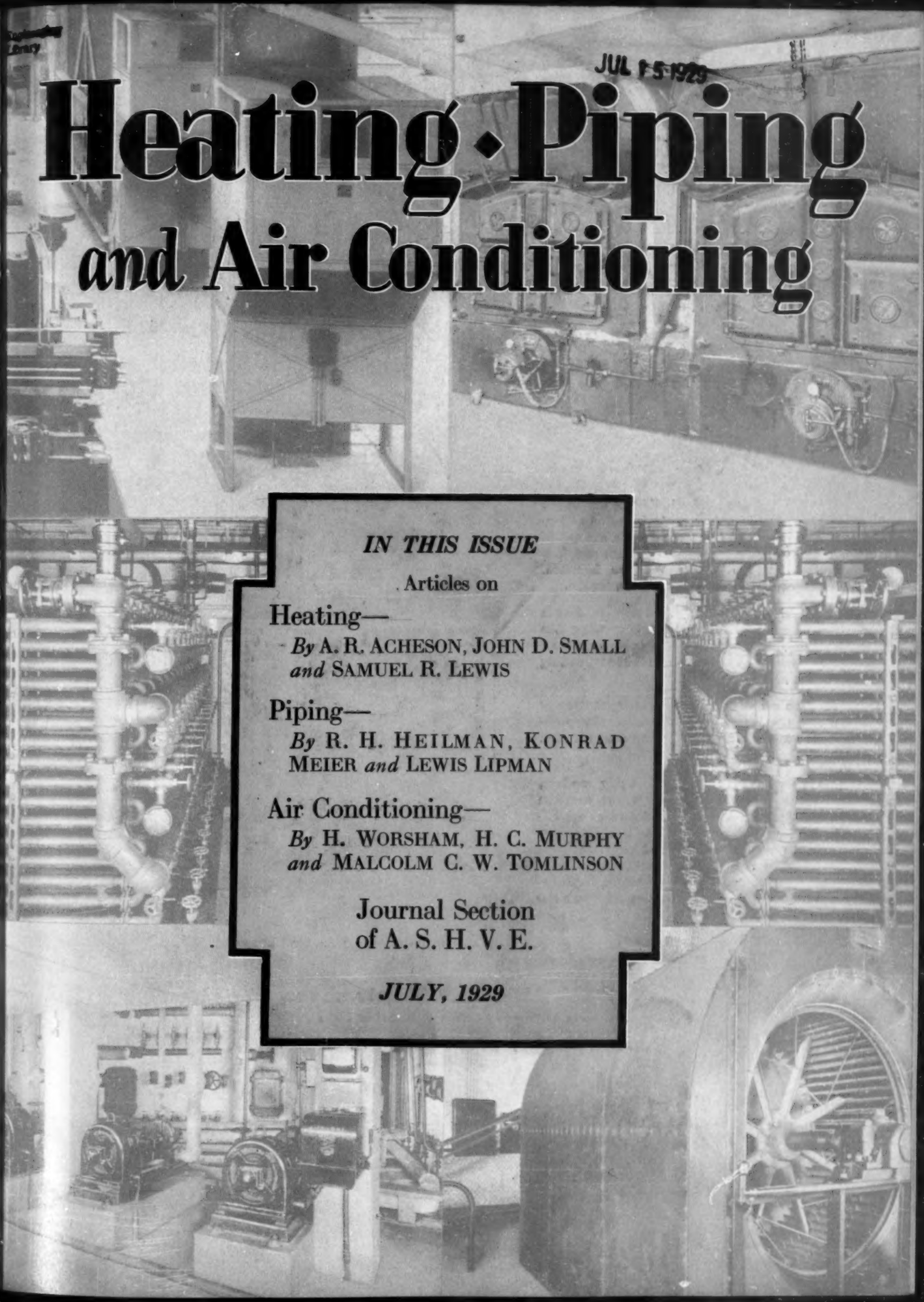
JUL 5 1929

Heating · Piping and Air Conditioning



IN THIS ISSUE

Articles on

Heating—

By A. R. ACHESON, JOHN D. SMALL *and* SAMUEL R. LEWIS

Piping—

By R. H. HEILMAN, KONRAD MEIER *and* LEWIS LIPMAN

Air Conditioning—

By H. WORSHAM, H. C. MURPHY *and* MALCOLM C. W. TOMLINSON

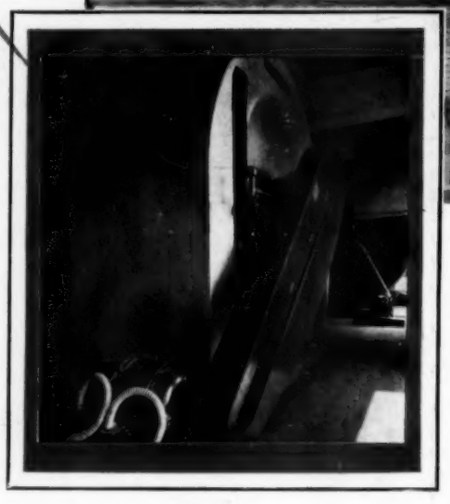
Journal Section
of A. S. H. V. E.

JULY, 1929

Fidelity-Philadelphia Trust Building

42 fans and 4 air washers

Fidelity-Philadelphia Trust Building. Broad St., Philadelphia, Pa.



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The EDITOR'S PAGE

Heating·Piping and Air Conditioning

Using Exhaust Steam

A. R. Acheson has for twenty years been head of the department of mechanical engineering at Syracuse University, carrying on an extensive consulting activity at the same time. He has been called in by many industrial plants to determine the possible economy of using exhaust steam for industrial heating and process work and employs a system for such determination which he describes in detail in his article appearing in this number—an article of great engineering value.

When Humidity Is Low

Malcolm Tomlinson is now with the Frost Research Laboratories in Norristown, Pa. Previous to this connection he was with one of the largest manufacturers of electrical appliances and equipment, in which position he gave exhaustive study to the use of low humidities for drying operations and for human comfort. His article in this issue is the first of four in which he will cover the subject of low humidities in every detail.

District Heating at Purdue

District heating engineers — in fact, any one interested in steam distribution —will find valuable information in the abstracts of several papers presented by Purdue University professors at the recent district heating school held at that institution.

CO_2 Piping for Refrigeration

H. L. Alt is a consulting engineer whose experience embraces a multiplicity of mechanical engineering activities here and abroad. His articles will appear from time to time. In this issue is one for the air conditioning engineer on the subject of CO_2 piping, used in refrigeration.

WE ROUND THE TURN OF THE FIRST QUARTER

This issue of HEATING, PIPING AND AIR CONDITIONING completes our first quarter. When it is possible to talk about a quarter of a year's activities, there isn't the feeling of newness that may have been apparent in the first two issues. While we want always to be new, in the sense of being up to the minute and live in our presentation of technical and practical data and information on this field, we like to feel now, as we round the first turn into the second quarter of our maiden year, that we are no longer new to our readers in the sense of being an experiment or a trial.

Following the practice of large corporations which issue quarterly statements on their business condition, we can report that our first quarter's production has included more than fifty articles on the various phases of heating, piping and air conditioning. These articles have been from the pens of authorities in this field. They have contained basic engineering principles which the engineer and contractor could interpret and apply to specific problems. They have contained practical suggestions which the engineer and contractor could put right to work without interpretation. They have been what our readers wanted and needed, judging from comments that have come to us. And they have been an assurance that future issues will make good on every promise to render a high grade engineering publishing service.

This particular issue is the biggest of them all. There are more articles in it than in either of the two before. Some of the writers have been introduced in either the first or second issue. The others appear for the first time, although their reputations as engineers make their introduction hardly necessary.

MEETING OUR READERS' NEEDS

While we prefer the qualitative method of analyzing our editorial pages, the index of which is the reputations of our authors and editors, still a few figures indicating in a quantitative manner the editorial content of the July issue of HEATING, PIPING AND AIR CONDITIONING will be of interest to our readers

Of sixty-one pages, (aside from the Journal section) twenty-three are devoted to piping, twenty-two and one-half to air conditioning, and the remaining fifteen and one-half to heating. These proportions, in view of the overlapping of interests, represent fairly the interests of our subscribers.

Thus we assure the greatest good to the greatest number—by a quantitative as well as a qualitative measure for our editorial pages.

INSULATING HIGH PRESSURE STEAM LINES

R. H. Heilman is senior fellow at the Mellon Institute of Industrial Research, University of Pittsburgh. He has made a thorough study of pipe insulation and is a writer from whom the reader can expect authoritative data in an article such as the one by him in this issue on insulating high pressure steam lines. High pressures and temperatures are one of the livest subjects in engineering today. The insulation phase of it is highly important.

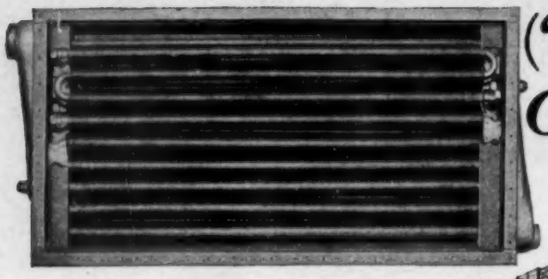
TO HELP CO-ORDINATE RESEARCH

Konrad Meier is a name that has commanded respect in the heating field for many years. He has written text books and many articles for leading technical journals in Europe and America. His article in this issue is descriptive of tests performed on pipe welding in Switzerland, and we offer it as part of our plan to co-ordinate research that has been conducted here and abroad, so that our readers may have all the information developed and results secured on practices in this field.

SPECIFICATIONS AS A FINE ART

John D. Small is a consulting engineer in Chicago. He has been identified with the heating and ventilating field for many years and has written hundreds of specifications. Mr. Small talks about the art of writing specifications in an interesting and informative manner in this issue, and we know of no one who knows more about the subject he has chosen.

—and in Patrick T. ("Paddy") Harmon's new Chicago Indoor Stadium



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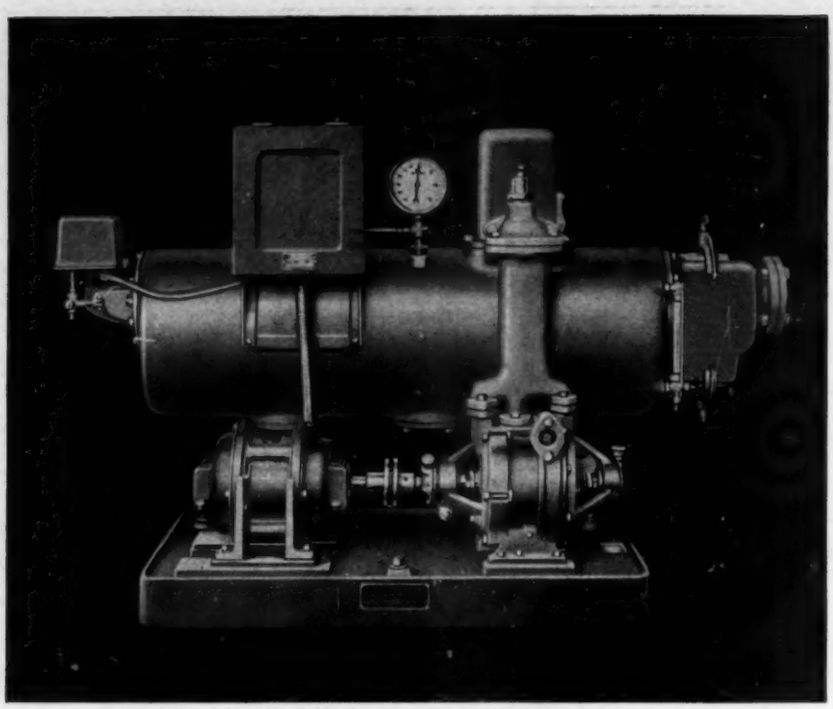

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Heating · Piping
and Air Conditioning

Vol. I | July, 1929 | No. 3

The Milam Building

FIG. 1. THE MILAM BUILDING, SAN ANTONIO, TEXAS

By Herman Worsham

San Antonio building of twenty-one stories is the first in the country completely equipped for air conditioning to provide year-'round comfort

SEVERAL office buildings are already equipped with complete systems of air conditioning and cooling for year-'round comfort. The Milam Building of San Antonio, Texas, owned by the Travis Investment Company, Inc., and opened in January, 1928 is the most completely equipped of all. It is a brick and reinforced concrete structure of 21 stories, the tallest structure in the world built without fabricated steel. It is air conditioned throughout, from the cafeteria in the basement to the roof, taking in several stores and a barber shop on the street floor and approximately 750 offices on the upper floors.

In many other respects—such as elevator equipment, lighting, floors and so on—this building stands out as a leader. The progressiveness of the owners was ably backed up by George Willis, the architect; M. L. Diver, the consulting engineer, and the contractors, L. T. Wright & Company, all of San Antonio.

The air conditioning and cooling system consists principally of eleven units of air conditioning equipment (fans, dehumidifiers, heaters, motors, etc., as shown in Figs. 2 and 3); two units of refrigeration (see Figs. 7 and 8) for cooling the spray water; water storage and distributing lines made up of tanks, pumps, piping, etc. (Fig. 9); air distributing ducts with grilles, dampers, etc. (Figs. 4, 5 and 6); and controls, both automatic and hand. In general, one air conditioning unit serves two floors, exceptions being the cafeteria in the basement, the street floor and the top typical floor (17th floor) each of which has its own unit, and the four tower floors which are served by one unit. All of the refrigerating and water cooling equipment with pumps, tanks, etc. are located in the basement.

The system is designed especially to take care of the summer time conditions, but it also takes care of the winter time conditions as well—taking away heat and humidity during the hot weather and adding them during cold weather. In the summer the maximum temperature inside is 80 deg. fahr. with a relative humidity not exceeding 55 per cent, while the inside winter temperature is 70 deg. fahr. or above with a relative humidity of approximately 45 per cent.

In determining the best conditions it was necessary to study the records of the local weather bureau. In doing this it was learned that San Antonio has many days of continuous bright sunshine coming through clear air which makes the heat of the sun quite a potent factor in the calculations and design. The hottest period of the day usually occurs around four o'clock in the afternoon and continues generally to seven or eight or nine o'clock. The climate is such that the natives are accustomed to higher temperatures, both in summer and winter, than are those of the northern cities and, consequently, they are comfortable at conditions slightly above what those of the north think of as the comfort zone.

After the proper atmospheric conditions are decided upon it is usually a simple matter to determine the size of the conditioning system. It must have sufficient capacity to absorb all the heat that is generated within the building—from sources such as lights, people, etc.—plus that which comes in from the outside. An office building—due to the nature of its construction and on account of the high ratio of the heat from a "traveling" sun to the total heat to be absorbed—offers a good many complications not found in the usual air conditioning problem.

Heat of the Sun

One of the biggest problems offered is that due to the heat of the sun. Few of us realize the tremendous value of this radiant heat. In most cases it is partly combated by a gradual absorption and distribution throughout the entire enclosure. In the case of an office building the interior is honeycombed with partitions—the average office in this building being approximately 1/1000 of the entire building—so that the heat absorbed by the wall of any particular office is effective mostly in that office. Without some means of individual control the temperature of an office exposed to the sun will likely be 8 deg. or 10 deg. higher than the temperature of one without sun. The air requirements in one case are approximately double what they are in the other.

This would not be so bad if the sun stood still, but it moves from one side of the building to the other. In the morning the east side offices get the sunlight and need the greatest amount of cooling, while in the afternoon the west side offices get the sunlight and offer the bigger cooling problem. Further complications are caused by cloudy days when there is no sun and a shifting wind, variable in velocity and direction. When it is remembered that these changes may occur hourly it is possible to get some idea of the magnitude of the problem.

The windows should be provided with a good shade, made of white material, to prevent the entrance of direct sunlight. This will reduce materially the heat to be absorbed and will aid in maintaining uniformity. The solid cloth shade is probably the best, although light does not enter as readily as with some other types. It reflects a good bit of the heat and tends to seal in between itself

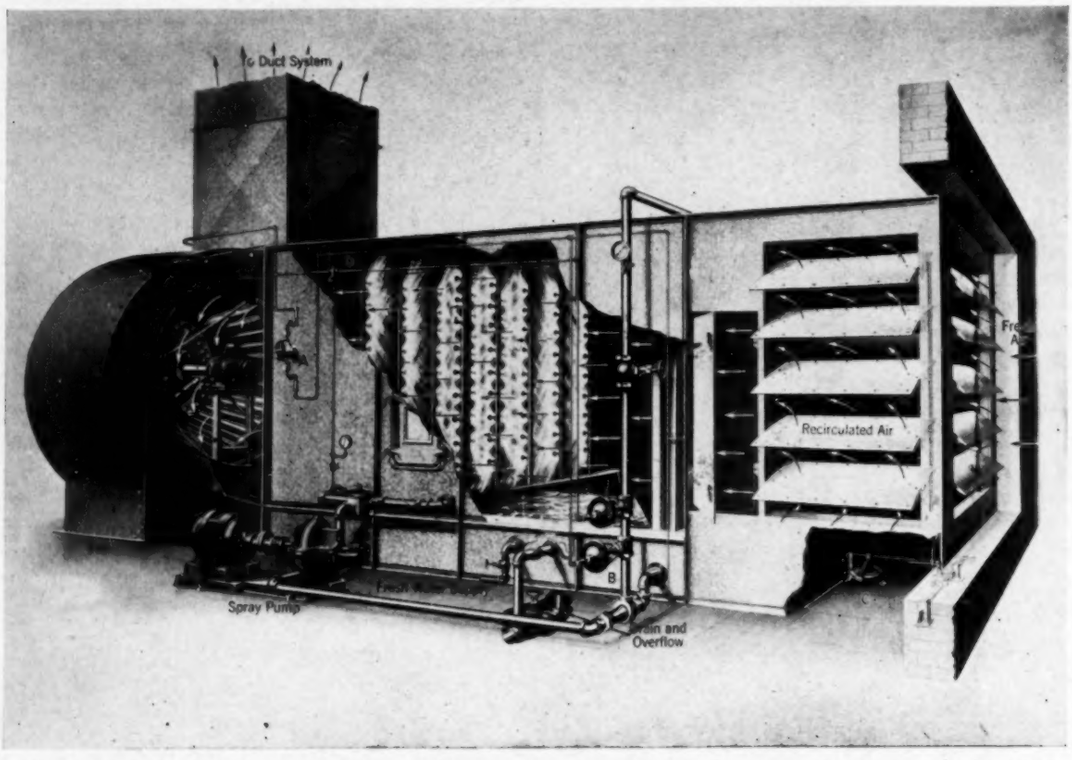


FIG. 2. A TYPICAL ARRANGEMENT OF THE EQUIPMENT WHICH CONDITIONS THE AIR, SHOWING THE FAN, DEHUMIDIFIER AND ACCESSORIES. ELEVEN OF THESE UNITS SERVE THE MILAM BUILDING

and the glass a strata of air which acts as an insulation. Awnings are even better in eliminating the sunlight heat. Venetian shades, of the adjustable type, are more satisfactory from the standpoint of light, but they let through considerable more heat due to their open areas. Roughly, white cloth shades stop about 50 per cent of the sunlight heat and adjustable Venetian shades about 25 per cent, while awnings stop practically all of it.

The variable load due largely to the changing sun can be combatted by a combination of individual room control and group volume control in the main supply ducts. Individual room control means individual heating units—for periods of the year when heating is required — placed preferably behind the air supply grills, and volume control of the entering air. Volume control to each office is difficult because of the small quantity of air handled and its low pressure. Group volume control is obtained by providing dampers which shift the greater part of the air to the side on which the sun is shining. Not often will the arrangement of the building permit this latter scheme to be very effective, but, used in conjunction with the other schemes, it is of material assistance.

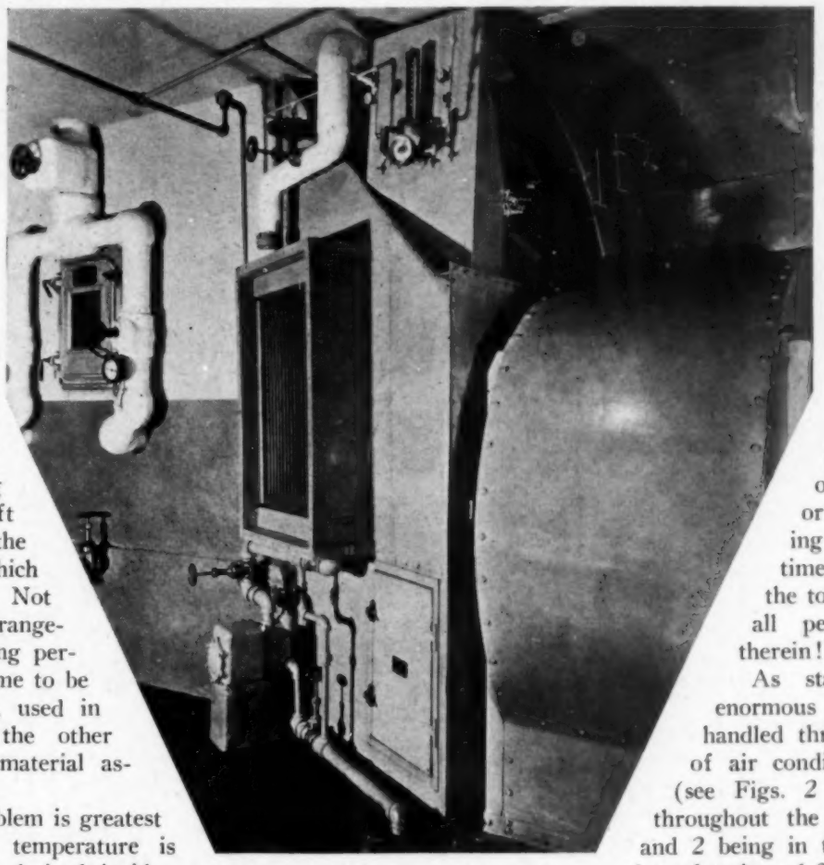


FIG. 3. AIR CONDITIONING UNIT NO. 1—DEHUMIDIFIER, HEATER, CONTROLS, FAN, ETC., SERVING THE CAFETERIA IN THE BASEMENT

The sunlight problem is greatest when the outside temperature is slightly below that desired inside—say 60 deg. fahr. At such a time those offices in the shade require heating while those in the sun require cooling—the sun heat being sufficient to warm them to the desired temperature. Under these conditions, individual heating units for each office maintain uniform conditions throughout.

Care should be taken not to load up the system with too much control. With a properly designed system, operating in conjunction with centrifugal refrigeration (see Fig. 7), a variable inside temperature is not as bad as it appears, because with the high temperatures a lower relative humidity exists and with the low temperatures a higher relative humidity exists. This means that the effective temperature change—the temperature to which our bodies are sensitive—is much less than the actual temperature change.

When the latter is 4 deg. the former is usually between 2 deg. and 3 deg.

Number of People and Lights

In addition to the sunlight heat and the inflow of heat through the walls, glass, etc., due to the higher outside temperature—they are two entirely distinct things—the calculations must take into consideration the number of people and the number of lights. It is difficult to plan for the individual office. When the number of people may average 2 or 3 per office, there may be certain offices under certain conditions that will have 6 or 8 times that number. The layout should be flexible enough to permit some local adjustment.

When all the sources of heat gain have been taken into consideration and totaled it is then necessary to determine the correct volume of air to give the proper temperature and relative humidity. In the case of the Milam Building, approximately eight tons of air are handled each minute—enough to give a complete net change of air once every 7 or 8 minutes—carrying several hundred times more oxygen than the total consumption of all people congregated, therein!

As stated before, this enormous quantity of air is handled through eleven units of air conditioning equipment (see Figs. 2 and 3) scattered throughout the building, Nos. 1 and 2 being in the basement (for the cafeteria and first floor) and No. 11 being on the 18th floor (for the four tower floors), the other eight being located in between—the typical layout having one unit for two floors. For the office floors the apparatus is located in the space between the rear building wall and the elevator shaft as shown on Fig. 4. Outside air is taken through a window opening and return air through louvres in the corridor wall.

Distribution of Air

The most important part of an air conditioning installation is the distribution of the air. Ordinarily, we would say that it is at least 75 or 80 per cent of the job. No matter how good the equipment in the basement or in the apparatus room is, if the air is not distributed properly the results will not be satisfactory. It must be carried to every point and circulated positively with nothing left to chance. Wherever there is trouble with

a system, four times out of five it is due to faulty air distribution. In no case is a system any better than its air distribution.

The problems met with in good air distribution are different for every building—no two being just alike. In every case the conditions must be studied before deciding upon the method and the layout, then based on a combination of engineering knowledge, experience and good common sense. In the case of the Milam Building the main air supply ducts are placed overhead in the corridor. They are built of galvanized iron sheets and plastered underneath to match the office ceilings. They are shallow enough so that the corridor ceiling is only 10 or 12 inches below that in the offices. The layout is clearly shown in Figs. 4, 5 and 6.

On account of the necessity of combating the changing sun light, as described above, the duct lines to both sides of the building must have sufficient area to carry the air required for maximum conditions—in this case about 75 per cent of the total volume handled. Dampers and air motors are placed in the duct leading to each side of the building and arranged so they can be operated by the engineer in the basement. He can shift the bulk of the air from one side to the other, depending on the location of the sun and, on cloudy days, equal division can be obtained.

From the main supply ducts branch connections are made to each office, the air supply grille being in the corridor wall near the ceiling.

In the branch connection to each office is a permanently set air volume adjuster which aids in giving uniformity of air flow and distribution. In addition to this, the air supply grille has a slide which enables the tenant to close off the air supply entirely if he so chooses.

One of the things that makes the duct layout to the offices difficult is the fact that the partitions are not permanent. Several offices may be thrown together as one large office or one office may be divided with several partitions. Where the added partitions do not reach to the ceiling the air distribution is not affected much but with full partitions duct extensions must be made to carry the air where it is needed. Several conventional arrangements were anticipated and standard duct extensions planned, but some of them are so special they must be planned on the job.

Return Air

For economical operations, both during the heating season and the cooling season, it is necessary to re-use a large portion of the air, re-conditioning and re-purifying it with the air conditioning equipment, drawing in just enough air from the out-of-doors to give good ventilation. The air delivered to the offices is returned to the corridor through a louvre opening in the lower part of the door and thence along the corridor to the apparatus back of the elevator shaft. In other words, the corridor serves as a return air duct.

In selecting the type of return air louvres for the office

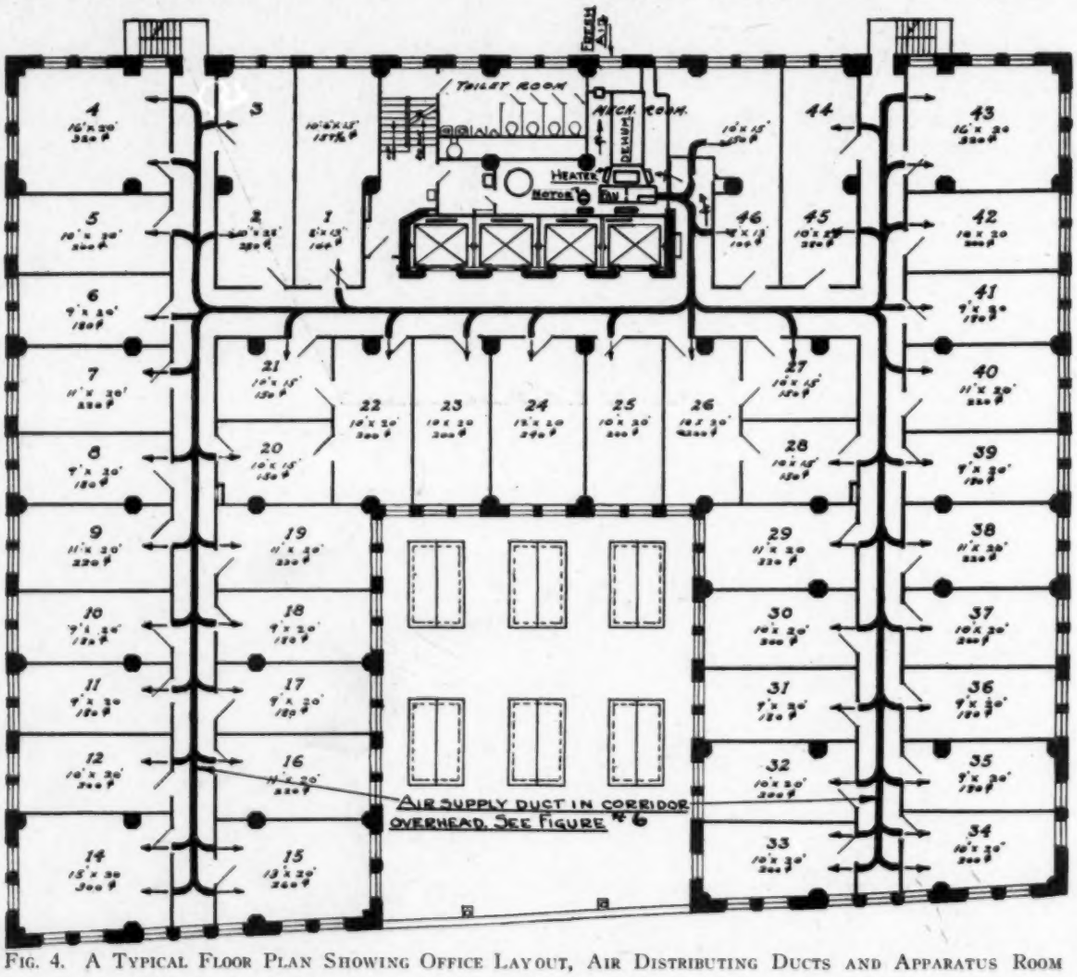


FIG. 4. A TYPICAL FLOOR PLAN SHOWING OFFICE LAYOUT, AIR DISTRIBUTING DUCTS AND APPARATUS ROOM

doors care must be taken to select one with plenty of free area affording unrestricted flow of air. At the same time, its design should be such that vision through it is impossible and that little noise will pass through it. In striving for complete noise absorption the resistance to free air flow may be built up to the point where a burden is thrown on the system, thereby making a compromise

Air Leakage

The tightness of the building is one thing that affects the quantity of fresh air to be used. The more air that leaks out through windows, doors and other openings, the more new air will have to be taken in. Windows are used throughout the Milam Building that make the entire structure quite tight. For this reason, little conditioned

FIG. 5. A TYPICAL LAYOUT OF THE AIR SUPPLY DUCTS—ERECTED BEFORE THE CEILING OR PARTITIONS WERE IN PLACE. THE CORRIDORS ARE DIRECTLY UNDERNEATH THE DUCTS. THE APPARATUS ROOM IS TO THE RIGHT OF THE ELEVATOR SHAFT

necessary. The type of louvre used in the Milam Building is the V-type. It affords free air flow; prevents vision through it; and is quite effective in preventing the transmission of sound.

No conditioned air is delivered directly to the toilets. They are ventilated by a separate exhaust, the source of supply being air leakage from the corridors and stair tower. This serves the double purpose of a partial outlet for the main system and a medium for slightly cooling the toilets.

The outside and return air dampers are under hand control. They are connected so that 100 per cent of outside air can be taken, or 70 per cent or 40 per cent or 15 per cent, depending on the scheme of operation and the existing weather conditions. All of them can be operated from the basement by the engineer. When cooling or heating is being accomplished there is no need for more outside air than that required for ventilation, and to take more simply increases the cost of operation. On the other hand, there are times when the outside conditions are just right and then it is desirable to take all air from the outside. The operating engineer is the best judge of the requirements—and for that reason in this particular case, manual control of the fresh air was preferable to automatic control.

air is wasted, which helps to keep the cost of operation down.

To give some idea of how serious air leakage through cracks around windows and doors might be, let us point out the great difference in weights of a column of air inside the building and one outside. In summer the air inside is heavier because it is cooler—denser. With a 20 deg. difference in temperature, a column of inside air one foot square and 200 feet high—20 stories—will weigh 0.6 of a pound more than an equal column of outside air. The total volume of air inside the building will weigh 7,500 pounds more than an equal volume outside! This column of dense air exerts a tremendous downward pressure, tending to force its way outward on the lower floors, and as it does, naturally, outside air is drawn in at the upper floors. The pressure is sufficient—with a 20 deg. difference—to create an outward velocity of 1,360 feet per minute through any cracks or crevices. During the winter season the air inside is lighter and the direction of air leakage is reversed—leaking in at the bottom and out at the upper levels. The whole building becomes a huge stack and, because the temperature differences in the winter are usually greater than in the summer, the action is even more pronounced. When this tremendous force for air leakage is understood the reasons

for a tight, well constructed building are apparent.

The air is conditioned before delivery to the offices by drawing it through sprays of finely divided water. For the summer the spray water is cooled to the desired temperature which in turn not only cools the air but fixes its moisture content as well—purifying and cleansing it at the same time. When the humidity is too high the excess moisture is condensed in the cold spray water just as moisture in the air is condensed on any cold surface. The colder the spray water the less moisture there is in the leaving air. During the winter, moisture is added by the spray—to bring the humidity up to the desired points, keeping it approximately constant all the time.

Bear in mind that there is nothing about the system which precludes the use of natural ventilation if desired.

A storage tank for cold spray water is provided under the basement floor. With this tank, the refrigeration equipment can be operated at times when the power rate is most favorable, thereby reducing the cost of operation. The capacity of the tank is such that sufficient cold water can be stored up, with one unit running during the night, to carry through the next day in connection with one unit in operation. If the storage water is not needed it can be held for several days with only a slight rise in temperature. Of course, there are a good many days when the tank alone—both refrigeration units shut down—has sufficient capacity to give enough refrigeration effect.

The use of storage water from the tank is under positive automatic control, the amount withdrawn

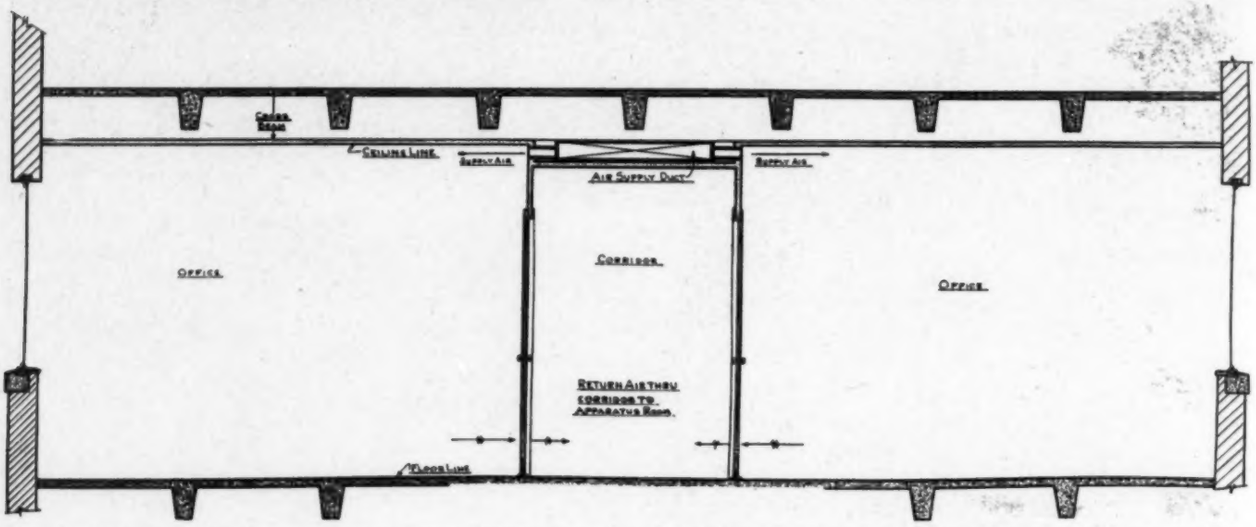


Fig. 6. This Is a Section of a Single Floor Showing the Air Supply Ducts Overhead in the Corridor. Notice the Return Air Louvres in the Lower Part of the Door

There is nothing to prevent a tenant closing the air supply leading to his office and depending upon the out-of-doors air which might enter through his open window.

The Cooling Equipment

The refrigeration and cooling equipment for the spray water are located in the basement. There are two units of centrifugal refrigeration which develop a capacity of 375 tons. The type of unit is shown in Fig. 7. Fig. 8 is a photograph of a portion of the room and Fig. 9 shows the arrangement of the two units with the tanks, pumps, etc. The space limitations necessitate the use of a compact system of refrigeration and the service demands simplicity and safety. Rental values are too high to use any more space than absolutely required for this purpose.

We can better visualize the refrigeration requirements under maximum conditions to think of it as ice—the cooling effect of 375 tons of ice—750,000 pounds—melting over a period of 24 hours. If this amount of ice were distributed equally to all the offices, each of them would have 1,000 pounds per day. Stacked in a column having the area of one of the elevator shafts it would extend from the basement to a point 30 or 40 feet above the tower of the building, a column of ice nearly 300 feet high—enough to serve a city of 75,000 people!

varying from zero to 100 per cent, depending upon the load. The construction of the tank is such that the returning water, relatively warm, does not mix directly with the cold tank water.

Spray water is delivered to the eleven air conditioning units by means of three centrifugal, motor-driven pumps, located, with the collection tank, in the refrigeration room. It was necessary to use an open system of water circulating lines, thereby losing the "head" due to the elevation of the water in the vertical risers. With this condition, dividing the eleven units into three groups permitted a saving in the total power consumption for pumping. Pump No. 1 is large enough to handle the entire quantity of spray water and at a pressure sufficient to deliver it to all the units on or below the 5th floor. Pumps No. 2 and No. 3 are booster pumps, the former supplying the units serving floors 6 to 14 inclusive and the latter all those above. There are no recirculating pumps located at the units so that instead of the usual settling tank underneath the dehumidifier there is merely a drainage tank. All the water is returned to the collection tank in the basement where it is again picked up, recooled if necessary and redistributed. About 1,200 gallons of water —5 tons—are sprayed per minute.

Control System

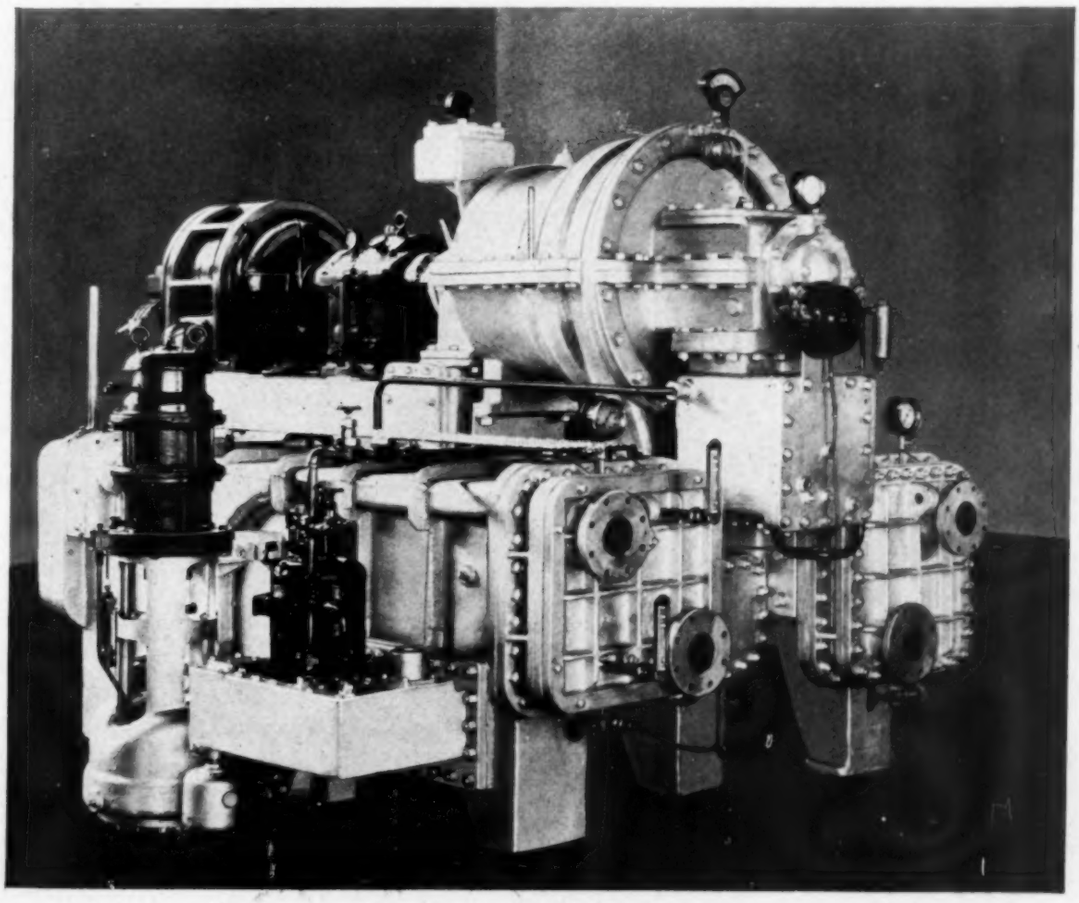
The entire system of control is a combination of manual and automatic operation. As stated above, care must be taken not to load up the installation with too many automatic devices. The point will be reached where the attention which they require will outweigh all of the theoretical advantages. It seems quite essential to provide the tenant with some means of adjustment,—something that he can manipulate when he feels that a change of conditions would be helpful. This is advisable even within a very limited range, if for no other reason than it relieves his mind; i. e., for psychological reasons. If he feels that a change is desirable, he is considerably relieved merely to feel that he has taken some action, more or less regardless of the results. So something should be left for the tenant to do, either regulation of the quantity of air or, in winter, access to the steam valve, where individual heating units are used.

In no case do we believe the volume of air entering an office should be automatically controlled. The chief reason for this is that a control instrument set for summer conditions will act just the reverse of what it should for winter conditions. In other words, if the instrument is set to give more cool air when the temperature is too high in the summer time, it will also give more air in the winter time when the temperature is too high but this time it will be warm air and the temperature will go even higher. So the instrument would have to be reversed from season to season. This would not be so bad if it happened just twice a year but there are many days when the requirements change hourly—one hour calling for cool air and the next warm air.

Where individual heating units are used for the offices separate automatic control would probably always be desirable. With individual heaters the air leaving the main supply would be relatively cool—say 60 deg. fahr.—thereby permitting adjoining offices to be maintained at temperatures widely different. In mild weather offices that required no heating would receive the cool air direct from the main supply while those that required heating could be heated individually to any extent desired.

The range of personal preference is so wide that individual heaters are almost essential for satisfaction to all. Frequently, among people of the same

FIG. 7. ONE OF THE TWO REFRIGERATING MACHINES USED IN THE MILAM BUILDING. EACH IS A COMPLETE REFRIGERATING AND WATER COOLING SYSTEM WITH COMPRESSOR AND MOTOR, CONDENSER (ON THE RIGHT), WATER COOLER (ON THE LEFT), AND ACCESSORIES. THE LARGER VERTICAL MOTOR ALONG SIDE THE WATER COOLER DRIVES THE LIQUOR PUMP WHICH FLOWS THE REFRIGERANTS OVER THE WATER-CARRYING TUBES, AND THE SMALLER MOTOR DRIVES THE EVACUATOR. ONE OF THESE UNITS, DEVELOPING 200 TONS OF REFRIGERATION AND COOLING 650 G. P. M. OF WATER, OCCUPIES APPROXIMATELY 215 SQ. FT. OF FLOOR AREA



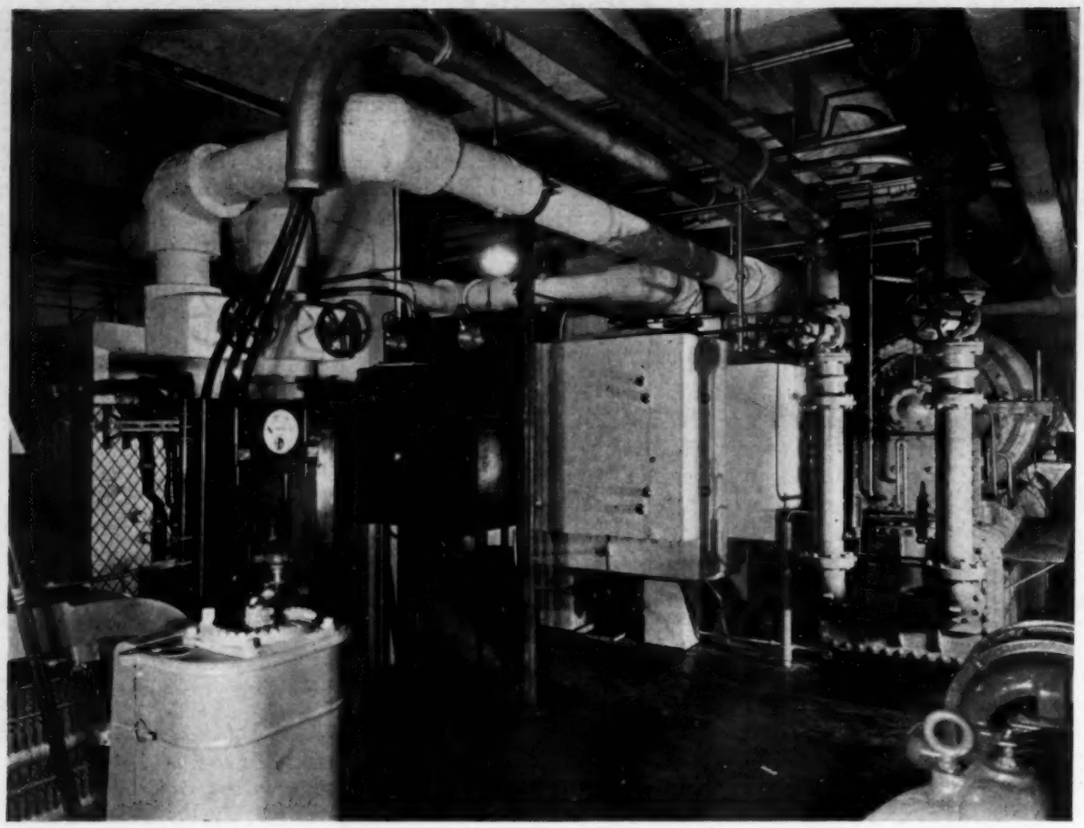


FIG. 8. A PORTION OF THE REFRIGERATION AND WATER COOLING ROOM SHOWING ONE OF THE UNITS. THE COMPRESSOR AND THE CONDENSER ARE AT THE EXTREME RIGHT, WITH THE WATER COOLER, INSULATED AND PLASTERED, ALONG SIDE

office there is a difference in personal preference of 6 deg. or 8 deg., one person wanting 70 deg. and another 76 deg. or higher. One man suggested a maximum temperature of 62 deg. fahr.! No doubt, his blood pressure was higher than his knowledge of the Fahrenheit temperature scale.

Wherever control parts are to be operated manually, it can be done by the engineer from his quarters in the basement. He can start or stop any of the air conditioning units at the main control panel or the same thing can be done directly at the unit. A signal system of red lights indicates when the units are in operation and which ones. Fire dampers, arranged to close in case of fire, are placed in both the supply and return ducts where they pass from one floor to another.

Cost of System Installed

The total cost of the system completely installed was $250,000.00. The installation, progressing with the construction of the building, covered a period of 18 months and five car loads of galvanized iron sheets were used. Not all of this money is to be charged to cooling and conditioning because winter heating is provided as well. There was a considerable saving in the elimination of all direct radiators and piping. In a good many cases, however, the use of direct radiation, or of some individual heating unit, will be well worth the additional cost. At least, some of the offices—those facing the cold exposures —should have some means of individual heating. If not some of the easy-heating offices will get too warm in bringing the temperature up to 70 deg. in the offices on the cold side.

The cooling system made unnecessary another thing that is considered standard equipment in office buildings of the south. There was no need to provide a ceiling fan for each office, so considerable money was saved by this omission. Transoms over the doors were also omitted. Altogether, the things made unnecessary by air conditioning amounted in money to about $100,000.00, reducing the cost of the latter to about $150,000.00.

San Antonio has very little cold weather and the temperature seldom goes below freezing. Heating systems for local buildings are usually calculated on a minimum outside temperature of 25 deg. fahr. Even during the winter season there may be long periods of hot weather, making it advisable to operate the cooling features of the air conditioning system. This means that the refrigeration equipment is in use part of the time of at least nine or ten months of the year. On the other hand, there may be days during the summer months when the desired conditions can be maintained without refrigeration. Ordinarily, the air handling equipment is started every day at about 6:30 A. M. and continued in operation until 10 P. M., the cooling features being used only when they are needed. Generally, it is considered better to operate the system on Sunday than to per-

mit the temperature to rise and attempt to pull it down early Monday. In this way the building has ideal conditions seven days a week.

Comfort, Health, Efficiency

The American people are giving more thought each year to comfort, health and personal efficiency. Evidence in support of this statement are the large number of theatres, auditoriums, stores, general offices and other gathering places that are air conditioned. Industry has long used this means of increasing production, improving quality and adding to the efficiency of machines. How much more important it seems to do all these things for the individual—the human machine! All of us know that we do more and better work when we feel good; when we are comfortable; when conditions are just right. There is not yet a way to measure absolutely, or relatively, the improvement, but we know it is there and when one considers the great number of people in our modern skyscraper—many of them spending a third of their time there—the results are tremendous.

City governments and individuals have been extremely careful for years about the water supply. Huge plants for making the water pure and safe are in operation everywhere and there are companies doing nothing but providing bottled water for drinking purposes. A pure water for drinking is highly desirable but we breathe nearly ten times as much air by weight as we drink water! Surely, good, pure air is just as desirable. Water can be dispensed with for a period of several days but life will not exist long—only a few minutes—without air.

Offices that are properly conditioned will bring a higher rental than otherwise and tenants are glad to pay the difference. It amounts to only a few cents a day and with two or three persons per office the additional cost seems even less. A 10 per cent or 15 per cent increase in rentals is not at all exorbitant for the benefits derived therefrom.

Another thing that makes the system worthwhile from the owner's standpoint is the fact that fewer offices will be vacant throughout the year. This is extremely important because often it is the revenue from the last few offices rented that makes the difference between profit and loss. After the income from rentals is sufficient to cover fixed and operating charges, any additional revenue or income is nearly all net profit. This emphasizes the importance of keeping the building well occupied.

An air conditioning system makes redecoration necessary less frequently. The walls, draperies, shades, etc., remain fresh and clean longer because windows can be kept closed, preventing dust and dirt from blowing in. Papers, documents, letters, etc., can be left out on top of a desk or table with the assurance that no sudden gust of wind from the window will disturb them and that they will not accumulate dust so readily.

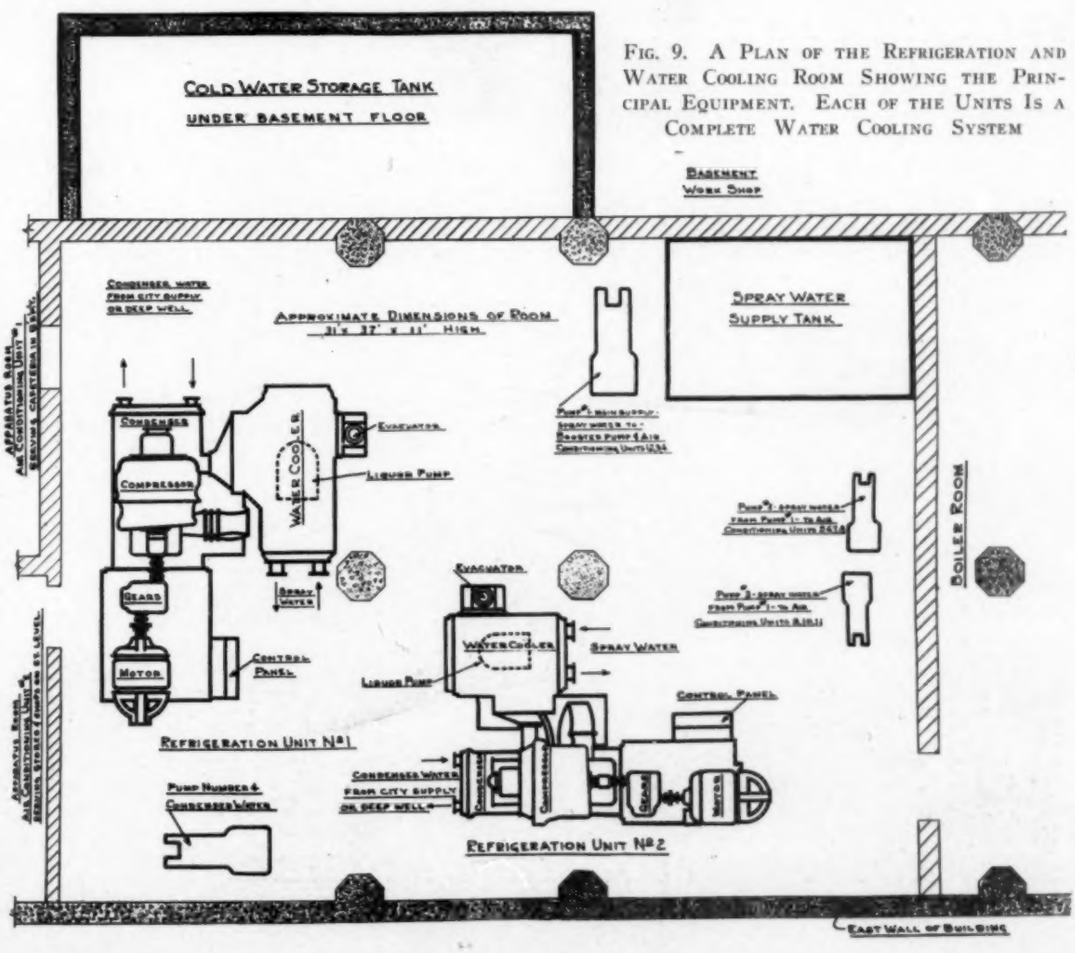


FIG. 9. A PLAN OF THE REFRIGERATION AND WATER COOLING ROOM SHOWING THE PRINCIPAL EQUIPMENT. EACH OF THE UNITS IS A COMPLETE WATER COOLING SYSTEM

Elimination of Noise

The most important feature in keeping the windows closed is the elimination of the confusion and disturbance due to noises from the outside. The greater part of even the tallest buildings are subject to street noises coming from electric cars, trucks, automobiles, new building construction, etc. This nuisance is one of the things responsible for the reduced rentals on the lower floors. With open windows, there are times, even on the tenth floor or higher, when conversation, especially over the telephone, is difficult—to say nothing of the abuse of one's disposition and peace of mind while engaged in the ordinary pursuit of the day's duties. Most of us can remember times when it became necessary to close the windows to accomplish some particular purpose. There are cases where the revenue from the lower floors scarcely pays for the investment therein; in other words, the lower floors could be left out, placing the upper floors on tall stilts without reducing materially the net income. This plight is greatly relieved with a system of air conditioning.

The cost of cleaning the building nightly is less. Fewer cleaners and scrubbers are used and they can finish the job in a shorter time. In the Milam Building each person of the cleaning force covers more area per unit of time than any other building of which we have knowledge. Air conditioning plays a prominent part in lowering the cost of cleaning.

Within a very few years many of us can live and work through a whole summer without experiencing many of the discomforts we know now. Our offices will be cool and comfortable; our homes will be maintained the same way; churches will be similarly provided for; and, our places of amusement, such as movies and play houses, many of which are already properly equipped, will be ready to entertain us. The American business man, always a leader in progressiveness, will, as soon as he learns how simply it can be attained, demand comfort in his office; he will demand it for his family in the home; and those who hope to serve him during recreation hours will have to provide it.

The windowless skyscraper, already envisioned by others and made possible by air conditioning plus artificial illumination, will surely become a reality since, for one thing, it can be erected on relatively inexpensive property. Let those who cry for "fresh" air through open windows from the out-of-doors be reminded that it doesn't exist in the congested city and let them be reminded further that now-a-days very few of our normal functions—functions such as locomotion, sustenance, habitation—are natural. The demands of modern life take us away from nature and, in doing so, develop substitutes that are a vast improvement. So air conditioning has come to make available every day the best in atmospheric comfort that nature offers so spasmodically.

Heating and Ventilating an Automobile Service Garage

THE PLANNING and construction of a service garage involves many considerations. Work routes and all partly enclosed spaces must be planned with reference to location of the heating and ventilating units. Carbon monoxide and other heavier than air gases tend to form pockets in obstructed corners. The well known dangers of carbon monoxide must be eliminated. The menace of carbon monoxide even in minute quantities has created a new attitude toward the subject of ventilation not only in garages but also in coal mining, gas manufacture, cleaning and dyeing establishments, etc

Ventilation in a garage is a necessary but high cost construction. On account of the excessive amount of air that is used and the necessity for heating quickly from ten to sixty degrees fahr., an adequate amount of heating equipment must be supplied.

How all these considerations were taken care of in one instance is explained in the following description of the heating and ventilating equipment and practice in the central service station for Cook County, Illinois, of the

FIG. 1. THE SERVICE STATION FOR COOK COUNTY, ILLINOIS, OF THE CHICAGO NASH CO.

Chicago Nash Company, a picture of which is shown in this article.

The strategic placing of unit heaters of the ventilator type in a building as extensive as this is achieved only through close co-operation between architect and engineer, with full knowledge throughout of all interested plant processes and operating conditions.

It is stated that these floor spaces with ramps instead of elevators and stairways have enabled the engineers and architects to provide more free working space than is found in most 10- to 12-story buildings. Passenger and freight elevators as well as multiple stair wells are very costly in space requirements and in power and time in shifting cars.

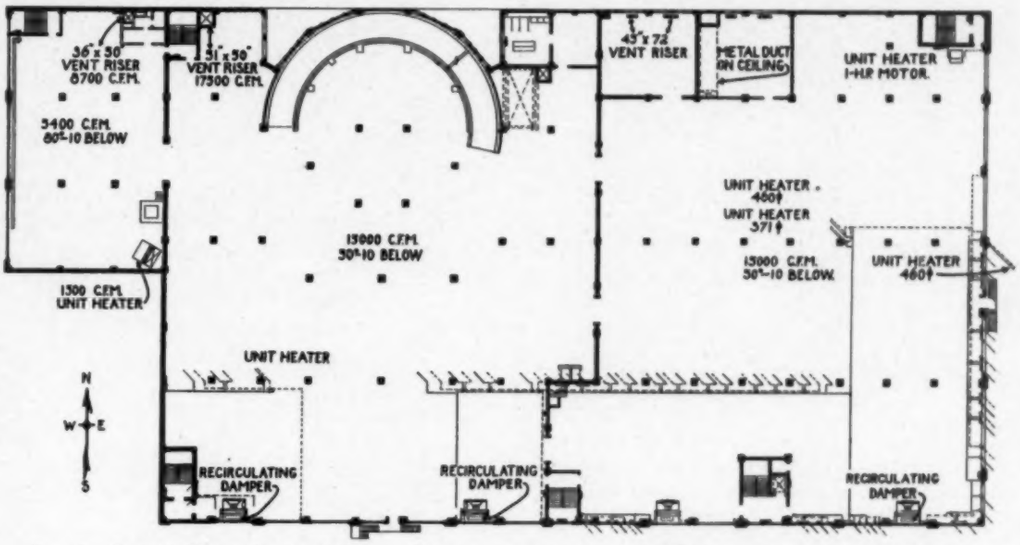


FIG. 2. SECOND FLOOR PLAN SHOWING VENTILATION SCHEME AND DISTRIBUTION OF UNIT HEATERS

For instance, a dividing screen erected as an after thought on one of the floors of the Chicago Nash station had to be replaced later by panels of open-meshed screen in order to restore the general air movement within the workshop. Aside from specific local problems that are met from time to time, a sufficient supply of fresh air with adequate diffusion is the chief consideration. Simplicity of piping and duct arrangement is always an object, and the use of few ducts with avoidance of indirect or short-circuiting air channels is important.

Such installations call for highly specific balancing of all factors involved, and much ingenuity in the placement of equipment for full service with dependable currents at all times for every point that may require protection. Air and heating costs are to be conserved wherever the space is used for storage purposes only, and any recirculation has to be effected without reduction of air change rate. Precision heat control devices have very special application in this field, particularly automatic control for off-duty hours or intermittent services.

Description of the Building

The central service station for Cook County, Illinois, of the Nash Company is 315 by 200 feet in size, three stories in height. On each floor are two rooms each with an area of about 34,000 square feet as well as a room of 6,000 square feet in the Indiana avenue annex. The total area of the two floors used for service work is 68,684 sq. ft., ceiling height of 13 ft. and cubical contents of 892,000 cu. ft.

These three-in-one spaces are practically unbroken for work purposes but may be separable in case of fire or if other need arises for separation of units.

There is parking space on an interior roof court for demonstration cars and automobiles driven by the staff. The officials drive their cars in at the front door, follow automatic traffic signals on a winding ramp upward from floor to floor and from one department to another, and finally park their cars in a convenient spot on the roof just outside their office doors, thus any casual entrance becomes an inspection tour through the plant. The cars ascend on their own power, require no elevator service and encounter no delays. The traffic signal system on the ramp makes it possible to move twenty cars up and five cars down in the cycle change of three minutes.

One's first impression of the interior of this building is one of vast spaces. The ample skylights are made to do double duty in daylighting, and in housing four large roof ventilators. The bench of every workman is directly beneath large windows, good working conditions being considered most important.

Heating and Ventilating

Heating and ventilating arrangements for the Chicago Nash building accounts for one-sixth of the construction costs. A duplex method of heating and ventilating is used. The system includes power, roof ventilators in constant operation equipped with fins of the propeller type, oil burners, low pressure boilers, unit heaters with fresh air direct intake, and fan diffusion, also cast iron radiators and cast iron blast heating coils on account of wide range of temperature fluctuation, 10 to 60 deg. fahr. and the air supply of 5,000 cu. ft. per minute per car in motion.

Additional radiation in the rooms is available for extreme conditions. A dual heat control system affords automatic daytime regulation and allows a

lower room temperature at night and during holidays or other non-working hours.

No floor space is taken up by radiators or unit heaters. All of the 27 unit heaters are ceiling suspended, and in several instances this installation has required the unit heater to be of special design for housing in an irregularly placed girder space, this being necessary for effective distribution.

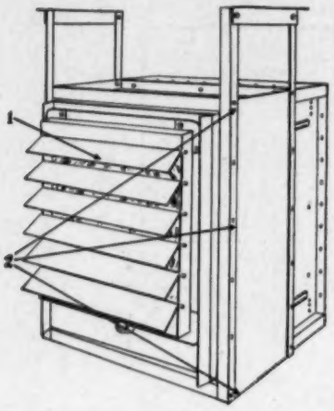


Fig. 3. Propeller Fan Unit Heater of the Type Installed in Chicago Nash Service Station

On the second floor there are four special unit heaters, each capable of introducing 12,300 cu. ft. of air per minute. Each of these unit heaters is equipped with a 42-in. propeller fan with air-cooled motor, direct connected. The power consumption of each unit is 800 watts per hour, speed of motor 490 r.p.m.

Also, there is provided 540 sq. ft. of cast iron blast heating coil per unit arranged in two rows with twenty sections in each row. This coil is capable of tempering the above amount of air from 10 to 60 deg. fahr. The damper arrangement permits 100 per cent of all unit heater capacities to be taken in from the outside and tempered to the required degree of heat, or 100 per cent recirculation is possible by an arrangement of dampers under control of heat regulating devices which open and close the dampers with the rise or fall of temperature in the room.

In addition to these units on this floor there is a unit heater having an air capacity of 6,800 C.F.M.,—this air for recirculation only. This unit is so located that it takes care of a considerable amount of window surface. It carries a 36-in. fan of propeller type with air-cooled motor, direct connected, whose power consumption is 642 watts per hour at 570 r.p.m. It is fitted with 486 sq. ft. of cast iron blast heating coil.

With the exception of two or three small private offices, all the executive offices in the third floor front section of the building are heated by means of six unit heaters of the ceiling suspension type. These units are of the recirculating type only and all are equipped with thermostatic heat regulating devices.

Some of the Ventilating Features

"The suitable ventilation of these large longitudinal areas gave us much concern," says John H. Harder, treasurer of the local company and manager of the plant. "Our earlier experience in rented space, depending upon improvised means of aeration, is responsible for the unusually elaborate provision we have made here for the safety and health protection of the men."

The ventilation plan throughout carries full recognition of the presence of carbon monoxide in car exhaust. It is a directional, one-way system. Forced exhaust is in constant operation and venting is capable of being speeded up for quick removal of noxious gases in event of an emergency. Vent flues open at floor and at points about six feet above the floor. The heated products of combustion are lighter than air and hence are effectively removed at higher levels. Floor level vents take care of heavier-than-

Fig. 4. Interior View of Plant Showing Three Large Unit Heaters in Place. The 55 Foot Span, With Floor Clear of Heating Equipment, Gives Unusual Expanse of Free Working Space

air fumes, and provide against any possible accumulation of gas on the floors.

The direct air inlets are under thermostatic control. Recirculation at irregular intervals avoids sudden and extreme temperature changes. There are several recirculating units for diffusion of heat. These

FIG. 5. FOUR SETS OF GRILLS SIMILAR TO THOSE SHOWN IN THE ILLUSTRATION EXHAUST AIR AT CEILING AND AT FLOOR LINE

units carry no ventilation duty, and in every case are placed where window space is ample for ventilation needs.

The air supply is figured on a basis of 5,000 cu. ft. of air per minute per car that is running. Operating conditions contemplate 100 per cent introduction and 75 per cent exhaust while cars are running, and the equipment is based upon the movement of not more than five cars per floor operating on their own power at the same time.

This provides an unusually wide margin of safety. How effective the one-way directional system is may be observed whenever a jet of smoke is emitted. Without any appreciable lag, the smoke drifts straight toward the exhaust vent directly opposite. This condition is positive throughout the plant, so much so that even the fires of the furnaces were unable to create a natural draft counter to room air currents, and fans had to be provided for forced draft for the forges.

The lacquer room has received special treatment. It is the usual custom to provide individual booths for cars that are being spray-painted. In this plant the entire spray room area of 6,000 sq. ft., or 72,000 cu. ft. is treated as one booth. Tempered air is constantly introduced to effect twelve changes of air per hour. An exhaust system on opposite side of the room pulls the air out through registers at the floor properly dampered to control fumes at their source wherever a car is being painted. All spray and fumes are kept out of the field of work.

On side of room opposite to heaters four sets of registers open into vertical stacks that go to the roof and exhaust through power roof ventilators. There is a register at ceiling line, and one at floor line of each of the four stacks on each floor.

The power roof ventilators consist of standard penthouses in which is installed a propeller fan with air-cooled motor. The front of the penthouse is fitted with an automatic shutter which opens and closes automatically with the operation of the fan.

The total exhaust on the second floor amounts to 38,800 C.F.M. The total capacity of air exhausted from the building amounts to 70,600 C.F.M.—this amount of air being handled with 12 H.P. The total horsepower necessary for all the unit heaters installed on this job aggregates 13¾ H.P.

Owing to the extremely high ratio here of floor space to window and wall areas, the room temperature regulation was made basic to ventilation estimates rather than on the basis of B.t.u. calculation. Efficiency rather than construction economy was the

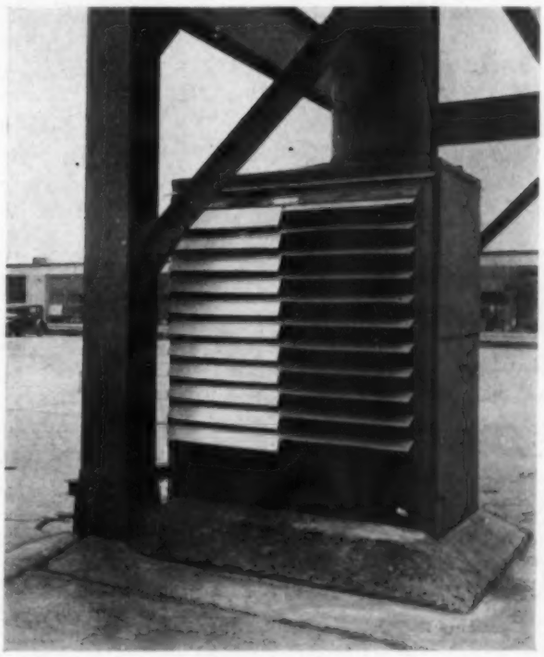


FIG. 6. ONE OF FOUR POWER ROOF VENTILATORS DRAWING AIR FROM VERTICAL TILE STACK

keynote. Seven large size unit heaters that take in air direct through openings to outside air are in constant operation on the two work floors. These distribute the heat and give the directional trend of the fresh air currents toward exhaust vents. There are twenty smaller fans at strategic points. The air exhausts through large vents placed at floor level or high up, according to the nature of the process.

George L. Klewer, of Chicago, was the architect. John R. Kehm, Chicago, did the heating, R. B. Hayward Co., Chicago, the ventilation equipment.

The Insulation of High Pressure Steam Lines

By R. H. Heilman

IN THE generation of high pressure steam, there has always been a tendency to increase the pressures and temperatures.

This tendency still exists, in spite of the fact that several years ago most engineers believed that the extreme limit in temperature had been reached, due to the well known phenomena of creep in metals.

The writer recalls a statement, made over six years ago by the head of the research department of a large steel company, that he believed that it was unsafe to subject steel pipe to the temperatures to which it was being subjected at that time.

However, the engineer is never content to stop, as long as greater efficiencies can be obtained by the use of higher pressures and temperatures. At present alloy steels are being investigated quite thoroughly, and the use of temperatures of 1,000 deg. fahr. will probably be common in the near future, with higher temperatures to follow.

The fact that engineers are willing to go to considerable trouble and expense to produce this high pressure heat is sufficient proof of the value of it, and it naturally follows that 1,000,000 B.t.u. at high pressure is more valuable than the same number of heat units at a low pressure.

It is, therefore, imperative that every precaution be taken to conserve this heat by preventing excessive losses from exposed surfaces, bare pipe, valves and fittings.

The use of a good heat insulation in sufficient thickness will conserve 95 per cent of the heat which would otherwise be lost from exposed high pressure surfaces, and, in addition to conserving the heat, the insulation will also improve working conditions around heated equipment, will produce more uniform products where temperature control and distribution is necessary, and will help to protect high pressure lines, brickwork, etc., from rapid temperature changes, thus minimizing the damage resulting from internal strains and cracks.

Heat Losses from Bare Surfaces

At the present time there are probably very few high pressure steam lines uncovered, as the engineering profession in general realizes the economies to be obtained from the use of high temperature insulation. On the other hand, however, there are still many valves and fittings on these high pressure lines left uninsulated. This is due sometimes to the fact that the first cost of insulating these fittings with removable coverings is rather high, and when it is necessary to have free access to them at frequent intervals the engineer is unwilling to cover them with permanent insulation. Usually, the real reason for leaving these fittings bare is the failure on the part of the engineer to realize the tremendous heat loss which results from having only a few fittings uncovered over an extended period of time, especially when the lines are operating at a high temperature.

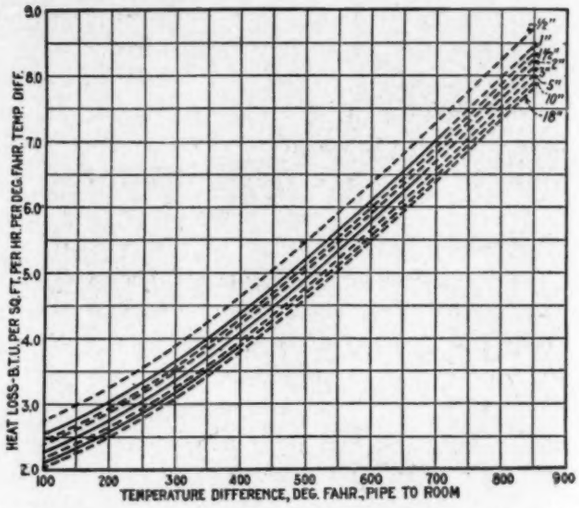


FIG. 1. CHART SHOWING HEAT LOSS FROM HORIZONTAL BARE STEEL PIPES

It is hard to ascertain the exact amount of heat lost per square foot of area from valves and fittings. In general, heat is lost from all exposed surfaces by radiation and convection. Radiation is proportional to the differences of the fourth powers of the absolute temperatures and depends upon the nature of the surface, but is independent of the shape of the surface. Convection is approximately proportional to the five-fourths power of the temperature difference and depends upon the shape of the surface.

Loss from Valves and Fittings

Careful tests conducted by the writer show that a 10-in. steam line at a temperature of 700 deg. fahr. loses 82 per cent of its heat by radiation. Since the loss by convection is small in comparison to the loss by radiation, it is suggested that the total loss from all valves and fittings per unit area be assumed the same as the unit area loss of an 18-in. pipe at the corresponding temperature.

In Fig. 1 is shown the heat loss from various diameter horizontal bare steel pipes at various temperature differences up to 850 deg. fahr. The loss is expressed in B.t.u. per square foot of pipe surface, per hour, per degree fahr. temperature difference between the pipe temperature and the room temperature.

The experimental values shown in Fig. 1 have been

transformed to pounds of coal and loss in dollars from 100 lineal feet of pipe per month at various steam pressures and temperatures. These values are shown in Table I.

While the data given in Fig. 1 and Table I have been published before, the values are of such importance to all users of heated equipment that they are well worth repeating. Also, the writer finds that there are still many engineers using the old rule of thumb method of calculating heat losses; namely, 2 B.t.u. per square foot of area per degree fahr. temperature difference, regardless of the temperature or diameter of the pipe.

An inspection of Fig. 1 indicates how erroneous this old rule is. The minimum value is found to be 2 B.t.u. for an 18-in. pipe at 100 deg. fahr. temperature difference, and this increases to a value of 7.75 B.t.u. at 850 deg. fahr. temperature difference.

Use of Compound Insulations

When insulating high pressure lines carrying temperatures above 500 deg. fahr. the usual practice is to insulate all lines above 2 inches in diameter with compound insulation, or with an inner layer of high temperature insulation over which is placed an outer layer of insulation more adapted to lower temperatures.

This procedure is necessary on account of the fact that the standard insulations must be protected from the destructive effects of high temperatures, by other materials capable of withstanding such high temperatures.

It is a well known fact that carbonate of magnesia begins to calcine at approximately 500 deg. fahr., and this calcination progresses until, at a temperature of about 1,000 deg. fahr., complete calcination has taken place.

This necessarily weakens the insulation considerably due to the change in the crystalline structure of the magnesia.

All asbestos papers or thin asbestos felts incorporate in their makeup a small percentage of inorganic binder. The binder, due to its organic nature, decomposes at higher temperatures, which results in a weakening of the asbestos felt construction.

Upper Limits for Standard Insulations

For these reasons the upper limits for sustained satisfactory service of these standard insulations is usually taken at 500 deg. fahr. to 550 deg. fahr.

There are many materials which will withstand the deteriorating effects of high temperatures, but those which will give satisfactory heat-insulating characteristics are rare. The insulation manufacturer, therefore, has a difficult task in selecting and incorporating materials which will produce a satisfactory insulation. So far, no high temperature insulation has been produced that can be placed on a high temperature line with as high an insulating efficiency as, say, 85 per cent magnesia would give if it would withstand the higher temperatures, and at a cost comparable to the cost of 85 per cent magnesia.

It is obvious that a single insulation which would operate satisfactorily and efficiently on both low and high pressure lines, thus doing away with compound insulation, would be very desirable. Perhaps, eventually, some one will produce such a covering, but until such time it will be necessary for the engineer to carefully design the insulation for all high temperature lines so as to determine accurately the correct ratio of inner to outer thickness of insulation, as well as the total economical thickness to use for his particular condition of operation.

As mentioned previously the maximum temperature to which the inner surface of the outer layer of insulation can be subjected is usually taken at 550 deg. fahr. To determine the temperature between the two layers of insulation requires some calculations.

An example illustrating this calculation as well as the determination of the outer surface temperature and heat loss through the insulation is given in the following paragraphs.

TABLE I—LOSSES FROM HORIZONTAL BARE IRON STEAM PIPES

From 100 lineal feet of pipe per month of 30 days with steam in pipes 24 hours per day. Coal at $4.00 per ton of 2000 lb.

Gage Press	Hot Water			10 Lb.			80 Lb.			120 Lb.			160 Lb.			200 Lb.			200 Lb. and 100° F. Superheat			275 lb. and 250° F. Superheat		
Temp.	180° F.			239.4° F.			324.0° F.			350.0° F.			370.7° F.			387.0° F.			487.9° F.			664.3° F.		
Pipe Size, Inches	Dollars Loss	Pounds Coal	B. T. U. per Lineal Ft. per °F. Diff. per Hr.	Dollars Loss	Pounds Coal	B. T. U. per Lineal Ft. per °F. Diff. per Hr.	Dollars Loss	Pounds Coal	B. T. U. per Lineal Ft. per °F. Diff. per Hr.	Dollars Loss	Pounds Coal	B. T. U. per Lineal Ft. per °F. Diff. per Hr.	Dollars Loss	Pounds Coal	B. T. U. per Lineal Ft. per °F. Diff. per Hr.	Dollars Loss	Pounds Coal	B. T. U. per Lineal Ft. per °F. Diff. per Hr.	Dollars Loss	Pounds Coal	B. T. U. per Lineal Ft. per °F. Diff. per Hr.	Dollars Loss	Pounds Coal	B. T. U. per Lineal Ft. per °F. Diff. per Hr.
½	1.32	526	.605	2.24	897	.670	3.92	1566	.779	4.51	1805	.815	5.25	2010	.846	5.53	2210	.875	8.60	3440	1.040	16.15	6460	1.375
1	1.91	763	.878	3.26	1305	.973	5.72	2290	1.138	6.25	2601	1.178	7.27	2910	1.242	8.07	3230	1.280	12.56	5026	1.520	23.84	9540	2.03
1½	2.65	1060	1.220	4.54	1818	1.357	7.98	3190	1.586	9.28	3710	1.676	10.42	4165	1.751	11.36	4550	1.804	17.94	7175	2.170	33.76	13500	2.87
2	3.24	1297	1.491	5.36	2142	1.600	9.78	3910	1.943	11.37	4549	2.052	12.75	5103	2.145	14.00	5600	2.220	22.10	8825	2.670	42.20	16890	3.590
2½	3.86	1545	1.778	6.65	2660	1.984	11.66	4660	2.320	13.66	5460	2.464	15.25	6100	2.564	16.70	6690	2.650	26.64	10650	3.220	50.50	20200	4.300
3	4.56	1824	2.100	8.24	3292	2.460	13.88	5550	2.760	16.14	6450	2.910	18.04	7210	3.030	19.84	7945	3.150	31.60	12640	3.820	58.25	24300	5.170
3½	5.18	2070	2.380	8.89	3554	2.655	15.82	6325	3.145	18.31	7322	3.305	20.50	8200	3.450	22.60	9040	3.580	35.90	14360	4.345	69.00	27600	5.860
4	5.78	2305	2.650	9.87	3950	2.950	17.70	7075	3.520	25.50	8200	3.700	22.85	9145	3.842	25.15	10060	3.981	40.10	16040	4.850	72.40	30920	6.580
4½	6.35	2540	2.920	10.94	4370	3.260	19.48	7790	3.878	22.60	9025	4.075	25.30	10120	4.250	27.75	11100	4.400	44.05	17620	5.326	85.60	34240	7.286
5	6.95	2780	3.200	11.97	4790	3.575	21.25	8500	4.232	24.62	9850	4.450	27.60	11050	4.650	30.40	12140	4.805	49.35	19740	5.960	94.50	37800	8.050
6	8.20	3280	3.775	14.21	5680	4.240	25.30	10110	5.024	29.30	11720	5.295	32.80	13120	5.522	36.00	14420	5.715	57.50	23000	6.955	112.50	45000	9.580
7	9.40	3760	4.325	16.18	6470	4.826	29.10	11640	5.782	33.70	13480	6.090	37.60	15040	6.324	41.60	16650	6.560	66.25	26500	8.010	129.00	51550	10.97
8	11.00	4398	5.050	18.25	7300	5.450	32.60	13030	6.455	37.65	15050	6.840	42.40	16940	7.125	46.05	18420	7.300	74.75	29900	9.050	146.20	58500	12.44
9	11.62	4650	5.350	20.35	8130	6.070	36.25	14500	7.210	42.10	16840	7.600	47.22	18900	7.950	51.98	20790	8.230	83.50	33400	10.10	162.60	65050	13.84
10	12.68	5065	5.925	22.05	8820	6.584	40.20	16100	8.010	46.70	18690	8.440	52.30	20910	8.805	57.75	23100	9.150	97.50	39000	11.18	180.00	72000	15.30
12	15.00	6000	6.995	26.44	10580	7.890	47.40	18950	9.425	55.40	22120	10.00	61.76	24700	10.40	70.00	28010	11.14	109.30	43700	13.22	213.50	85500	18.18
14	16.60	6635	7.625	28.90	11560	8.620	52.00	29800	10.34	60.50	24200	10.92	67.50	27000	11.36	74.10	29650	11.76	119.40	47740	14.43	233.00	93300	19.85
16	18.82	7525	8.650	32.80	13120	9.790	58.76	23500	11.70	68.40	27320	12.34	76.10	30410	12.80	84.25	33700	13.35	135.00	54000	16.34	265.00	106000	22.55
18	21.00	8400	9.650	36.10	14460	10.80	65.40	26150	13.00	76.50	30570	13.80	85.50	34200	14.38	93.75	37500	14.87	151.20	60500	18.30	297.50	119000	25.30

In these tables coal has been figured at $4.00 per ton of 2,000 lb.—13,000 B.t.u. per lb. of coal—labor, boiler room expense, etc., taken at $1.00 per ton, making total value of coal fired at $5.00 per ton. Boiler efficiency taken at 70 per cent Air Temp. 70°F. experimental data obtained at the Mellon Institute.

Calculation of Heat Losses and Temperature Gradients

In order to be able to calculate heat losses through an insulation it is necessary to know the temperature at the inner and outer surface of the insulation. Ordinarily the pipe temperature, or inner surface temperature, and the room temperature are known. However, the temperature at the outer surface of the insulation is not known.

TABLE II—VALUES OF $\frac{564}{D^{0.19}}$

D Inches	$\frac{564}{D^{0.19}}$	D Inches	$\frac{564}{D^{0.19}}$	D Inches	$\frac{564}{D^{0.19}}$	D Inches	$\frac{564}{D^{0.19}}$	D Inches	$\frac{564}{D^{0.19}}$
3.00	458	5.0	415	8.5	375	12.0	351	18.0	325
3.25	451	5.5	408	9.0	371	12.5	349	19.0	322
3.50	445	6.0	401	9.5	367	13.0	346	20.0	319
3.75	439	6.5	395	10.0	364	14.0	341	21.0	316
4.00	433	7.0	390	10.5	361	15.0	337	22.0	313
4.25	428	7.5	385	11.0	357	16.0	333	23.0	310
4.50	423	8.0	380	11.5	354	17.0	329	24.0	308

It has been found that the temperature at the outer surface of the insulation depends upon the amount of heat transmitted through the insulation, upon the temperature of the surrounding air and also upon the outer diameter of the insulation. A great many tests which have been conducted, measuring the temperature of the outer surface of the insulation at the same time that the heat loss through the insulation was measured, indicated that a certain law existed, and that this law was always the same for unpainted canvas surfaces regardless of the nature or conductivity of the insulation, but depended upon the diameter of the outer surface of the insulation. This law, which has been put in the form of an equation by the writer, is as follows:

$$Td = \frac{272.5\ h}{h + \frac{.564}{D^{0.19}}}$$

or

$$h = \frac{564\ Td}{D^{0.19}\ (272.5 - Td)}$$

in which Td=temperature difference between canvas surface and room deg. fahr.

h=total B.t.u. loss per hour per square foot of canvas surface.

D=outer surface diameter, in inches.

The above quotations are approximately accurate for diameters up to 24 inches. The loss from a flat surface cannot be expressed by these equations, but to enable one to arrive at an approximate flat surface temperature it is suggested that the equations be used, assuming D to be a 30 in. pipe, when

$$Td = \frac{272.5\ h}{h + 295} \quad \text{or} \quad h = \frac{292\ Td}{272.5 - Td}$$

Values of $\frac{564}{D^{0.19}}$ are given in Table II for various diameters of insulation.

By the use of these equations one is able to calculate readily the heat loss through an insulation if the temperature difference between the canvas surface and the surrounding air is known; or, vice-versa, if the heat loss is known, the temperature difference, and, hence, the canvas temperature of the insulation can be readily calculated.

As mentioned previously, usually only the pipe temperature and room temperature are known and the heat loss and temperature gradients have to be calculated.

Assume Outer Surface Temperature

Probably the simplest procedure for calculating the loss through an insulation is to make an assumption of the outer surface temperature, then from the mean conductivity curve (which can be secured from the manufacturer or published test results) determine the conductivity of the material at the mean of the surface temperature assumed and the known inner surface temperature.

The loss through the covering should then be calculated for the assumed outer surface temperature, and this loss should be checked against the loss as obtained from the surface loss curve or equation. If the two losses do not check, the assumed outer surface temperature must be changed according to the indications of the calculation and the process repeated until the two losses or the outer surface temperatures check. At first this may seem to be a very tedious method, but with the aid of a slide rule and Table II one will find that the loss through single and compound sections can be accurately calculated in a very short time.

The determination of heat transmission through compound sections is more difficult than the calculations for single sections.

The labor involved in making the calculations increases proportionately as the number of the sections is relatively increased.

The equation for compound sections on a cylindrical surface in terms of heat loss per square foot of outer surface is:

TABLE III—HEAT INSULATION SPECIFICATIONS

For Temperatures from 700 deg. fahr. to 800 deg. fahr.

	Pipe Temperature 700° Fahr.						Pipe Temperature 800° Fahr.			
Pipe Size Inches	Inner Layer Thickness Inches	Outer Layer Thickness Inches	Temp. °F. at Inner Magnesia Surface	Canvas Temp °F with Air at 70° F.	B.T.U. Loss per Lineal Foot per Hour		Temp. °F. at Inner Magnesia Surface	Canvas Temp. °F. with Air at 70° F.	B.T.U. Loss per Lineal Foot per Hour	
					Covered Pipe	Bare Pipe			Covered Pipe	Bare Pipe
½	2	None	.....	114	101.2	1.116	.....	121	119.5	1.447
¾	2	None	.....	117	113.0	1.365	.....	123	132.5	1.773
1	2	None	.....	120	126.2	1.681	.....	127	148.6	2.188
1¼	2	None	.....	123	144.0	2.104	.....	130	168.5	2.742
1½	2	None	.....	125	156.4	2.391	.....	133	182.7	3.119
2	1	2	444	107	130.0	2.948	502	113	154.4	3.851
2½	1	2	455	109	145.0	3.536	515	115	171.5	4.626
3	1	2	463	111	163.0	4.275	528	118	193.0	5.597
3½	1¼	2	436	110	169.0	4.852	494	116	200.5	6.357
4	1½	2	417	109	176.0	5.430	470	115	208.5	7.121
4½	1¼	2	421	110	188.5	5.980	475	116	223.2	7.891
5	1½	2	430	112	207.5	6.654	480	118	244.0	8.736
6	1½	2	432	113	227.0	7.887	490	120	270.0	10.360
7	1½	2	437	114	251.0	9.058	496	121	296.8	11.900
8	1½	2	442	116	274.5	10.230	500	123	326.0	13.450
9	1½	2½	470	112	270.0	11.400	533	118	320.0	14.990
10	1½	2½	474	113	292.0	12.710	538	120	347.0	16.710
12	1½	2½	479	114	334.0	15.000	543	121	397.0	19.740
14	1½	2½	482	115	356.0	16.380	546	122	423.0	21.570
16	1½	2½	485	117	396.0	18.660	550	124	472.0	24.570
18	1½	2½	489	118	438.0	20.970	555	125	521.0	27.620
Flat	1½	2½	514	126	75.8	4.228	584	134	90.3	5.560

For temperatures between 700 deg. Fahr. and 800 deg. Fahr. reasonably accurate values can be obtained by interpolating the tables given above.

$$h = \frac{T_1 - T_2}{\frac{r_s \log e \frac{r_2}{r_1}}{K_1} + \frac{r_s \log e \frac{r_3}{r_2}}{K_2} + \frac{r_s \log e \frac{r_4}{r_3}}{K_3}}$$

in which

T_1 = temperature of inner surface of insulation

T_2 = temperature of outer surface of insulation

r_1 = radius of inner surface of 1st section

r_2 = radius of outer surface of 1st section

r_3 = radius of outer surface of 2nd section

r_s = radius of outer surface of last section

K_1 = conductivity of 1st section

K_2 = conductivity of 2nd section

The various steps involved in the solution of a problem of this type will be illustrated by an example.

Example. Calculate the heat flow in B.t.u. per hour per square foot of pipe surface through a compound insulation on an 8-in. pipe, consisting of a first layer of a high temperature insulating material 1.5 inches thick, and a second layer of 85 per cent magnesia, 2 inches thick. Determine the temperature at the inner surface of the 85 per cent magnesia and also the canvas temperature. The temperature of the pipe is 800 deg. fahr. and the room temperature is 70 deg. fahr.

First, a canvas temperature of 120 deg. fahr. is assumed. The total drop in temperature through the two coverings then is $800 - 120 = 680$ deg. fahr. The next step is to assume the temperature drop through each insulation, in order to determine the conductivity value to use. No rule can be given for the first assumption, but it will be found that the second assumption can be calculated fairly closely. It is to be expected from what has been said previously in regard to the relative insulating values of the two materials that the drop through the high temperature insulation should be less than the drop through magnesia, so there is first assumed a drop of 300 deg. fahr. through the former and a drop of 380 deg. fahr. through the latter.

The temperature between the high temperature and the magnesia covering, then, is $800 - 300 = 500$ deg. fahr.

The mean temperature of the high temperature covering is

$$\frac{800 + 500}{2} = 650 \text{ deg. fahr.}$$

and from the conductivity curve $K_1 = 0.676$. The mean temperature of magnesia is

$$\frac{500 + 120}{2} = 310 \text{ deg. fahr., and } K_2 = 0.509.$$

Now

$$r_1 = 4.3125$$
$$r_2 = 5.8125$$
$$r_3 = 7.8125$$

$$r_s \log e \frac{r_2}{r_1} = 2.33$$

TABLE IV—PRICE LISTS—85% CARBONATE OF MAGNESIA PIPE-COVERINGS

For Wrought Iron Pipes

Nominal Pipe Size Inches	Thickness of Standard Covering Inches	Price per Lineal Foot Canvas Jacketed	Thickness of Covering Inches	Price Per Lineal Foot Canvas Jacketed	Thickness of Covering Inches	Price per Lineal Foot Canvas Jacketed	Double Layer Double Standard Thickness Inches	Price per Lineal Foot Canvas Jacketed	Double Layer Total Thickness 3 In. Inches	Price per Lineal Foot Canvas Jacketed
⅜	⅜	$0.22	1½	$0.46	2	$0.75	1¾	$0.65	3	$1.20
¾	⅜	.24	1½	.49	2	.80	1¾	.70	3	1.35
1	⅜	.27	1½	.52	2	.85	1¾	.75	3	1.40
1¼	⅜	.30	1½	.56	2	.90	1¾	.80	3	1.45
1½	⅜	.33	1½	.60	2	.95	1¾	.85	3	1.55
2	1⅛	.36	1½	.64	2	1.00	2⅛	.90	3	1.65
2½	1⅛	.40	1½	.70	2	1.05	2⅛	1.00	3	1.75
3	1⅛	.45	1½	.76	2	1.15	2⅛	1.10	3	1.90
3½	1⅛	.50	1½	.82	2	1.25	2⅛	1.20	3	2.05
4	1⅛	.60	1½	.88	2	1.35	2¼	1.40	3	2.20
4½	1⅛	.65	1½	.94	2	1.45	2¼	1.50	3	2.35
5	1⅛	.70	1½	1.00	2	1.55	2¼	1.60	3	2.50
6	1⅛	.80	1½	1.10	2	1.70	2¼	1.80	3	2.70
7	1¼	1.00	1½	1.20	2	1.85	2½	2.25	3	2.90
8	1¼	1.10	1½	1.35	2	2.00	2½	2.50	3	3.15
9	1¼	1.20	1½	1.50	2	2.20	2½	2.70	3	3.40
10	1¼	1.30	1½	1.65	2	2.40	2½	2.90	3	3.65
*12	1½	1.85	1½	1.85	2	2.70	3	4.10	3	4.10
14	1½	2.10	1½	2.10	2	3.00	3	4.60	3	4.60
16	1½	2.35	1½	2.35	2	3.30	3	5.10	3	5.10
18	1½	2.60	1½	2.60	2	3.60	3	5.60	3	5.60
20	1½	2.85	1½	2.85	2	4.00	3	6.00	3	6.00
24	1½	3.30	1½	3.30	2	4.50	3	7.00	3	7.00
30	1½	4.00	1½	4.00	2	5.50	3	8.40	3	8.40

*All coverings larger than 10 inches furnished in segment form; jackets and bands not included.

Double standard thickness—the inner layer is furnished in sections for pipe sizes up to and including 10 inches, and in curved blocks for larger sizes. The outer layer is furnished in sections for pipe sizes up to and including 8 inches, and in curved blocks for larger sizes.

Double 1½-inch thickness—the inner layer is furnished in sections for pipe sizes up to and including 10 inches, and in curved blocks for larger sizes. The outer layer is furnished in sections for pipe sizes up to and including 7 inches, and in curved blocks for larger sizes.

$$r_s \log e \frac{r_3}{r_2} = 2.31$$

Substituting the values obtained above in the equation,

$$h = \frac{800 - 120}{\frac{2.33}{0.676} + \frac{2.31}{0.509}} = \frac{680}{3.45 + 4.54} = 85.1 \text{ B.t.u.}$$

Substituting this value in the surface loss equation, there is obtained

$$Td = \frac{272.5 \times 85.1}{85.1 + \frac{564}{15.6} - 0.19} = 55.3$$

This indicates that 50 deg. fahr. temperature difference first chosen was too low, and there is next assumed a temperature difference of 55 deg. fahr., or a canvas temperature of 125 deg. fahr., since the canvas temperature will generally be fairly close to the canvas temperature first obtained by substituting in the surface loss equation.

The temperature drop through the high temperature insulating material for the foregoing calculation was approximately 3.45×85.1, or 293.5 deg. fahr., while the temperature drop through magnesia was approximately 4.54×85.1, or 386.5 deg. fahr. Since there has been assumed a canvas temperature increase of 5 deg. fahr., there will be assumed a corresponding decrease in the drop through the covering, or the tempera-

ture drop through the high temperature covering as 292 deg. fahr. and the drop through magnesia as 383 deg. fahr., with the temperature between the two coverings as 508 deg. fahr.

The mean temperature of the high temperature covering, then, is

$$\frac{800 + 508}{2} = 654 \text{ deg. fahr.}$$

and $K_1 = 0.677$. The mean temperature of the magnesia covering is

$$\frac{508 + 125}{2} = 316.5 \text{ deg. fahr., and } K_2 = 0.512.$$

Then

$$h = \frac{675}{\frac{2.33}{0.678} + \frac{2.31}{0.512}} = 85.5 \text{ B.t.u.}$$

Checking again for the canvas temperature difference,

$$Td = \frac{272.5 \times 85.5}{85.5 + 335} = 55.4 \text{ deg. fahr.}$$

This value checks very well with the last value of 55 deg. fahr assumed, and the heat loss is 85.5 B.t.u.

The total heat loss per square foot of pipe surface per hour is, then

$$\frac{85.5 \times 7.8125}{4.3125} = 154.8 \text{ B.t.u.}$$

The temperature drop through the high temperature insulating material is

$$\frac{2.33 \times 85.5}{0.678} = 290 \text{ deg. fahr.}$$

The temperature at the inner surface of the magnesia, therefore, is 800 — 290 = 510 deg. fahr., and the canvas surface is 55.4 + 70 or 125.4 deg. fahr.

The above example illustrates the method used in proportioning compound insulation. One can readily see that the most economical design is to keep the inner layer or high temperature covering as thin as possible without raising the temperature at the inner surface of the outer layer above 550 deg. fahr. If the insulation could be obtained in a great many thicknesses the ratio of the two thicknesses could be determined so as to obtain any intermediate temperature desired.

However, in the manufacture and sale of pipe coverings, as well as of any other commodity, it is desirable, for obvious reasons, to limit the number of standard thicknesses as much as possible, and since the two different insulations are required to fit snugly together, increasing the number of thicknesses of the high temperature insulation necessarily increases the number required of the lower temperature insulations. In practice, owing to vibration, etc., the usual procedure is to design the installation so that the intermediate temperature is quite frequently below 500 deg. fahr.

A set of specifications recommended by one manufacturer for pipe temperatures of 700 deg. and 800 deg. fahr. using standard thickness coverings is shown in Table III. In this table the B.t.u. loss per lineal foot of bare and insulated pipe and the intermediate and canvas surface temperatures are given.

Savings Resulting from Proper Insulation of Superheated Steam Surfaces

The fact that a 4-in. thickness of pipe covering, when applied to an 18-in. pipe operating at a temperature of 800 deg. fahr., will pay for itself in a period of 42 days with steam at only 35 cents per 1,000,000 B.t.u., is of sufficient importance to arouse the interest of any engineer who is at all concerned with the conservation of fuel.

There are many instances where the proper insulation of exposed or under-insulated surfaces would repay the original cost many times over in one year; for example, exposed fittings, under-insulated steam lines, boilers, ovens, and temporary heating appliances used in chemical and plant laboratories. The fact that pipes are covered does not end the possibility of heat losses. It is the poorest economy to use a minimum thickness of covering on high pressure lines and apparatus when the use of a thicker covering will not only result in greater efficiency, but will quickly pay for itself in the extra heat saved. The length of time required to repay the original cost of the investment depends, of course, on the cost of the heat which would otherwise be lost and upon the cost of the covering as applied, together with the annual fixed charges.

Costs Vary

The cost of heat varies considerably in various plants and localities, so that calculations based on one cost of steam would obviously be applicable only to that particular case. Some of the factors which influence the cost of steam are cost of fuel, heat content of the fuel, efficiency of the installation, method of firing, load factor, charges against the investment in boiler plant, and operating charges.

Some of the factors which influence the cost of the insulation as applied are initial cost of material, labor rate per hour, amount of cement work compared with straight pipe and blocks, number of fittings and bends compared with straight pipe, accessibility of pipes, painting, weight of canvas and application of canvas (pasted or stitched).

The cost of application of the covering varies for different plants as mentioned above. However, one large pipe covering contractor finds for his work that in general the actual cost of covering for superheated steam lines to the central station in place and finished is approximately the list net price of the covering.

The price list of 85 per cent magnesia covering is shown in Table IV. This list is used in quoting prices on all types of covering on the market at present. The actual cost of any given type of insulation is quoted at so many points off the list price.

In order to form a definite comparison, the author has chosen for the cost of covering as applied, list net, and list—20 per cent., and the cost of fuel at the boiler nozzle of 15, 20, 25, 30 and 35 cents per 1,000,000 B.t.u. There are many cases where the actual cost and application of pipe covering will exceed the list price of the covering and there are also many cases where the cost of steam will greatly exceed 35 cents per 1,000,000 B.t.u.

In order to make intelligent use of Tables V and VI shown, it will be necessary for the engineer first to

TABLE V—TIME REQUIRED TO REPAY ORIGINAL COST AND SAVINGS PER YEAR

Pipe Temperature—Deg. fahr.		650					700					750				
2" Pipe	Fuel Cost / Material	.15	.20	.25	.30	.35	.15	.20	.25	.30	.35	.15	.20	.25	.30	.35
		1" th. H.-T. 1½" th. Mg.					1" th. H.-T. 1½" th. Mg.					1" th. H.-T. 2" th Mg.				
Covering and application List	Months Required....	6.3	4.7	3.8	3.2	2.7	5.5	4.1	3.3	2.7	2.3	5.9	4.5	3.6	3.0	2.5
	Saving per year.....	2.38	3.24	4.09	4.94	5.79	2.77	3.75	4.73	5.71	6.69	3.25	4.40	5.56	6.72	7.88
Covering and application List—20%	Months Required....	5.0	3.8	3.0	2.5	2.2	4.4	3.3	2.6	2.2	1.9	4.7	3.6	3.8	2.4	2.0
	Saving per year.....	2.44	3.30	4.15	5.00	5.85	2.83	3.81	4.79	5.77	6.75	3.29	4.44	5.60	6.76	7.92
4" Pipe	Material	1" th. H.-T. 2" th. Mg.					1" th. H.-T. 2" th. Mg.					1½" th. H.-T. 2" th. Mg.				
Covering and application List	Months Required....	5.9	4.5	3.6	3.0	2.5	5.0	3.8	3.1	2.5	2.2	5.1	3.8	3.0	2.5	2.2
	Saving per year.....	4.36	5.90	7.49	9.03	10.60	5.20	7.04	8.86	10.70	12.54	6.13	8.29	10.45	12.60	14.75
Covering and application List—20%	Months Required....	4.7	3.6	2.8	2.4	2.0	4.0	3.0	2.4	2.0	1.7	4.0	3.0	2.4	2.0	1.7
	Saving per year.....	4.42	5.46	7.55	9.09	10.66	5.26	7.10	8.92	10.76	12.60	6.20	8.36	10.51	12.67	14.82
6" Pipe	Material	1" th. H.-T. 2" th. Mg.					1" th. H.-T. 2" th. Mg.					1½" th. H.-T. 2" th. Mg.				
Covering and application List	Months Required....	4.9	3.7	2.9	2.5	2.1	4.2	3.1	2.5	2.1	1.8	4.2	3.1	2.5	2.1	1.8
	Saving per year.....	6.46	8.73	10.99	13.26	15.54	7.68	10.34	13.06	15.71	18.39	8.99	12.15	15.28	18.42	21.57
Covering and application List—20%	Months Required....	3.9	2.9	2.4	2.0	1.7	3.3	2.5	2.0	1.7	1.4	3.8	2.5	2.0	1.7	1.4
	Saving per year.....	6.53	8.80	11.06	13.33	15.61	7.75	10.41	13.13	15.78	18.46	9.09	12.25	15.38	18.52	21.67
8" Pipe	Material	1½" th. H.-T. 2" th. Mg.					1½" th. H.-T. 2" th. Mg.					1½" th. H.-T. 2" th. Mg.				
Covering and application List	Months Required....	5.3	4.0	3.2	2.6	2.3	4.5	3.3	2.7	2.2	1.9	3.4	2.6	2.0	1.7	1.5
	Saving per year.....	8.38	11.34	14.30	17.26	20.72	10.00	13.50	17.00	10.50	24.00	11.74	17.84	19.92	24.21	28.09
Covering and application List—20%	Months Required....	4.2	3.2	2.5	2.1	1.8	3.6	2.7	2.1	1.8	1.5	3.0	2.3	1.8	1.5	1.3
	Saving per year.....	8.47	11.43	14.39	17.35	20.81	10.09	13.59	17.09	19.59	24.09	11.84	17.94	20.02	24.31	28.19
10" Pipe	Material	1½" th. H.-T. 2" th. Mg.					1½" th. H.-T. 2" th. Mg.					1½" th. H.-T. 2" th. Mg.				
Covering and application List	Months Required....	5.1	3.8	3.0	2.5	2.2	4.3	3.2	2.6	2.1	1.8	3.7	2.8	2.2	1.8	1.6
	Saving per year.....	10.44	14.10	17.80	21.50	25.10	12.43	17.78	21.10	25.50	29.88	14.63	19.70	24.80	29.85	34.90
Covering and application List—20%	Months Required....	4.0	3.0	2.5	2.0	1.7	3.4	2.6	2.1	1.7	1.5	2.9	2.2	1.8	1.5	1.3
	Saving per year.....	10.55	14.21	17.91	21.61	25.21	12.55	17.90	21.22	25.02	29.92	14.75	19.82	24.92	29.92	35.02
12" Pipe	Material	1½" th. H.-T. 2" th. Mg.					1½" th. H.-T. 2" th. Mg.					2" th. H.-T. 2" th. Mg.				
Covering and application List	Months Required....	4.8	3.6	2.9	2.3	1.9	3.9	2.9	2.3	1.9	1.7	4.1	3.1	2.4	2.0	1.8
	Saving per year.....	11.90	16.10	20.30	24.45	28.65	14.80	19.95	25.10	30.25	35.40	17.30	23.30	29.30	35.35	41.40
Covering and application List—20%	Months Required....	3.9	2.9	2.2	1.9	1.6	3.1	2.3	1.9	1.6	1.3	3.3	2.4	2.0	1.6	1.4
	Saving per year.....	12.03	16.23	20.43	24.58	28.78	14.93	20.08	25.23	30.38	35.53	17.46	23.46	29.46	35.51	41.56
14" Pipe	Material	1½" th. H.-T. 2" th. Mg.					1½" th. H.-T 2" th. Mg.					2" th. H.-T. 2" th. Mg.				
Covering and application List	Months Required....	4.6	3.5	2.8	2.3	2.0	3.9	3.0	2.4	2.0	1.7	4.2	3.0	2.4	2.0	1.7
	Saving per year.....	13.68	18.33	23.08	27.88	32.58	16.18	21.78	27.38	33.08	38.18	18.94	25.49	32.09	38.83	45.24
Covering and application List—20%	Months Required....	3.7	2.8	2.2	1.9	1.6	3.1	2.4	1.9	1.6	1.3	3.2	2.4	1.9	1.6	1.4
	Saving per year.....	13.82	18.47	23.22	28.02	32.72	16.32	21.92	27.52	33.22	38.82	19.11	25.66	32.26	39.01	45.41
16" Pipe	Material	1½" th. H.-T. 2" th. Mg.					1½" th. H.-T. 2" th. Mg.					2" th. H.-T. 2" th. Mg.				
Covering and application List	Months Required....	4.6	3.4	2.7	2.3	2.0	3.8	2.9	2.3	1.9	1.6	3.9	2.9	2.3	1.9	1.7
	Saving per year.....	15.40	20.80	26.20	31.60	37.00	18.40	24.80	31.20	37.60	44.00	21.55	29.15	36.65	44.15	51.65
Covering and application List—20%	Months Required....	3.6	2.7	2.2	1.8	1.6	3.0	2.3	1.8-	1.5-	1.3-	3.1	2.3	1.9	1.6	1.3
	Saving per year.....	15.56	20.96	26.36	31.76	37.16	18.56	24.96	31.36	37.76	44.16	21.74	29.34	36.84	44.34	51.84
18" Pipe	Material	1½" th. H.-T. 2" th. Mg.					1½" th. H.-T. 2" th. Mg.					2" th. H.-T. 2" th. Mg.				
Covering and application List	Months Required....	4.4	3.3	2.6	2.2	1.9	3.7	2.8	2.2	1.9	1.6	3.7	2.8	2.2	1.9	1.6
	Saving per year.....	17.35	23.43	29.53	35.63	41.63	20.73	27.93	35.13	41.38	49.63	24.28	32.73	41.18	49.58	58.48
Covering and application List—20%	Months Required....	3.5	2.6	2.1	1.8	1.5	3.0	2.2	1.8	1.5	1.3	3.0	2.2	1.8	1.5	1.3
	Saving per year.....	17.52	23.60	29.70	35.80	41.80	20.90	28.10	35.30	41.55	49.80	24.48	32.93	41.38	49.78	59.18
Flat Surface	Material	1½" th. H.-T. 2½" th. Mg.					1½" th. H.-T. 2½" th. Mg.					2" th. H.-T. 2½" th. Mg.				
Covering and application List	Months Required....	3.9	2.9	2.3	2.0	1.8	3.3	2.5	2.0	1.7	1.4	3.2	2.4	1.9	1.6	1.4
	Saving per year.....	3.52	4.74	5.98	7.20	7.94	4.19	5.64	7.09	8.54	9.99	4.93	6.64	8.35	10.05	11.77
Covering and application List—20%	Months Required....	3.1	2.4	1.9	1.6	1.4	2.7	2.0	1.6	1.3	1.1	2.5	1.9	1.5	1.2	1.1
	Saving per year.....	3.56	4.78	6.02	7.24	7.98	4.23	5.68	7.13	8.58	10.03	4.97	6.68	8.39	10.09	11.81

TABLE VI—TIME REQUIRED TO REPAY ORIGINAL COST AND SAVINGS PER YEAR

Pipe Temperature—Deg. fahr.		800					850					900				
	Fuel Cost	.15	.20	.25	.30	.35	.15	.20	.25	.30	.35	.15	.20	.25	.30	.35
2" Pipe	Material	1" th. H.-T. 2" th. Mg.					1" th. H.-T. 2" th. Mg.					1" th. H.-T. 2" th. Mg.				
Covering and application List	Months Required....	5.1	3.8	3.1	2.6	2.2	4.5	3.4	2.7	2.2	1.9	4.1	3.0	2.4	2.0	1.7
	Saving per year.....	3.78	5.13	6.47	7.79	9.13	4.35	5.88	7.39	8.93	10.44	4.85	6.54	8.23	9.93	11.62
Covering and application List—20%	Months Required....	4.1	3.1	2.5	2.1	1.8	3.5	2.7	2.2	1.8	1.5	3.3	2.4	2.0	1.6	1.4
	Saving per year.....	3.82	5.17	6.51	7.83	9.17	4.39	5.92	7.43	8.97	10.48	4.89	6.58	8.27	9.97	11.66
4" Pipe	Material	1½" th. H.-T. 2" th. Mg.					1½" th. H.-T. 2" th. Mg.					1½" th. H.-T. 2" th. Mg.				
Covering and application List	Months Required....	4.4	3.3	2.6	2.2	1.9	3.8	2.9	2.3	1.9	1.6	3.4	2.5	2.0	1.7	1.5
	Saving per year.....	7.13	9.62	12.11	14.61	17.11	8.22	11.08	13.95	16.80	19.65	9.31	12.53	15.75	18.97	22.20
Covering and application List—20%	Months Required....	3.5	2.6	2.1	1.8	1.5	3.1	2.3	1.8	1.5	1.3	2.7	2.0	1.6	1.4	1.2
	Saving per year.....	7.20	9.69	12.18	14.68	17.18	8.29	11.15	14.02	16.87	19.72	9.38	12.61	15.83	19.04	22.27
6" Pipe	Material	1½" th. H.-T. 2" th. Mg.					1½" th. H.-T. 2" th. Mg.					1½" th. H.-T. 2" th. Mg.				
Covering and application List	Months Required....	3.6	2.7	2.2	1.8	1.6	3.2	2.4	1.9	1.6	1.4	2.8	2.1	1.7	1.4	1.2
	Saving per year.....	10.47	14.00	17.72	20.37	24.97	12.10	16.28	20.47	24.65	28.80	13.79	18.55	23.27	28.00	32.77
Covering and application List—20%	Months Required....	2.9	2.2	1.7	1.5	1.2	2.5	1.9	1.5	1.3	1.1	2.2	1.7	1.3	1.1	1.0
	Saving per year.....	10.57	14.19	17.82	20.47	25.07	12.20	16.38	20.57	24.75	28.90	13.89	18.65	23.37	28.10	32.87
8" Pipe	Material	1½" th. H.-T. 2" th. Mg.					1½" th. H.-T. 2" th. Mg.					1½" th. H.-T. 2" th. Mg.				
Covering and application List	Months Required....	3.0	2.2	1.8	1.5	1.3	2.6	1.9	1.5	1.3	1.1	2.3	1.7	1.4	1.1	1.0
	Saving per year.....	13.69	18.44	23.15	27.89	32.64	15.78	21.19	26.59	32.09	37.49	18.05	24.19	30.39	36.59	42.79
Covering and application List—20%	Months Required....	2.6	2.0	1.6	1.3	1.1	2.3	1.7	1.4	1.1	1.0	2.0	1.5	1.2	1.0	0.9
	Saving per year.....	13.79	18.54	23.25	27.99	32.74	15.88	21.29	26.69	32.19	37.59	18.15	24.29	30.49	36.69	42.89
10" Pipe	Material	1½" th. H.-T. 2" th. Mg.					1½" th. H.-T. 2" th. Mg.					1½" th. H.-T. 2" th. Mg.				
Covering and application List	Months Required....	3.2	2.4	1.9	1.6	1.4	2.8	2.1	1.7	1.4	1.2	2.4	1.8	1.5	1.2	1.0
	Saving per year.....	17.05	22.40	28.80	34.70	40.50	19.60	26.35	33.10	39.85	46.60	22.50	30.20	37.90	45.60	53.30
Covering and application List—20%	Months Required....	2.5	1.9	1.5	1.3	1.1	2.2	1.6	1.3	1.1	0.9	1.9	1.4	1.2	1.0	0.8
	Saving per year.....	17.17	23.02	28.92	34.82	40.62	19.72	26.47	33.22	39.97	46.72	22.62	30.32	38.02	45.72	53.42
12" Pipe	Material	2" th. H.-T. 2" th. Mg.					2" th. H.-T. 2" th. Mg.					2" th. H.-T. 2" th. Mg.				
Covering and application List	Months Required....	3.5	2.6	2.1	1.8	1.5	3.1	2.3	1.8	1.5	1.3	2.7	2.0	1.6	1.4	1.2
	Saving per year.....	20.10	27.10	33.10	40.10	37.10	23.20	31.20	39.20	47.20	55.20	26.60	35.70	44.80	54.05	63.20
Covering and application List—20%	Months Required....	2.8	2.1	1.7	1.4	1.2	2.5	1.8	1.5	1.2	1.1	2.2	1.6	1.3	1.1	0.9
	Saving per year.....	20.26	27.26	33.26	40.26	47.26	23.36	31.36	39.36	47.36	55.36	26.76	35.86	44.96	54.21	63.36
14" Pipe	Material	2" th. H.-T. 2" th. Mg.					2" th. H.-T. 2" th. Mg.					2" th. H.-T. 2" th. Mg.				
Covering and application List	Months Required....	3.4	2.6	2.0	1.7	1.5	3.0	2.3	1.8	1.5	1.3	2.6	2.0	1.6	1.3	1.1
	Saving per year.....	22.04	29.64	37.44	44.94	52.64	25.44	34.24	42.46	57.74	60.54	29.16	39.16	49.16	59.16	69.16
Covering and application List—20%	Months Required....	2.8	2.1	1.7	1.4	1.2	2.4	1.8	1.4	1.2	1.0	2.1	1.6	1.3	1.1	0.9
	Saving per year.....	22.21	29.81	37.51	45.11	52.81	25.61	34.41	43.13	51.91	60.71	29.33	39.33	49.33	59.33	69.33
16" Pipe	Material	2" th. H.-T. 2" th. Mg.					2" th. H.-T. 2" th. Mg.					2" th. H.-T. 2" th. Mg.				
Covering and application List	Months Required....	3.4	2.5	2.0	1.7	1.4	2.9	2.2	1.8	1.5	1.3	2.6	1.9	1.5	1.3	1.1
	Saving per year.....	25.15	33.85	42.55	51.15	59.95	28.95	38.95	48.95	58.85	68.85	33.15	44.55	55.95	67.25	78.65
Covering and application List—20%	Months Required....	2.7	2.0	1.6	1.3	1.2	2.3	1.8	1.4	1.2	1.0	2.0	1.5	1.2	1.0	0.9
	Saving per year.....	25.34	34.04	42.74	51.34	60.04	29.14	39.14	49.14	59.04	69.04	33.34	44.74	56.14	67.44	78.84
18" Pipe	Material	2" th. H.-T. 2" th. Mg.					2" th. H.-T. 2" th. Mg.					2" th. H.-T. 2" th. Mg.				
Covering and application List	Months Required....	3.2	2.4	1.9	1.6	1.4	2.8	2.1	1.7	1.4	1.2	2.5	1.8	1.5	1.2	1.1
	Saving per year.....	28.33	38.13	47.98	57.63	67.48	32.68	43.88	55.08	66.28	77.48	37.18	50.08	62.98	75.68	88.43
Covering and application List—20%	Months Required....	2.6	1.9	1.5	1.3	1.1	2.2	1.7	1.3	1.1	1.0	2.0	1.5	1.2	1.0	0.8
	Saving per year.....	28.53	38.33	48.18	57.83	67.68	32.88	44.08	55.28	66.48	77.68	37.38	50.28	63.18	75.88	88.68
Flat Surface	Material	2" th. H.-T. 2½" th. Mg.					2" th. H.-T. 2½" th. Mg.					2" th. H.-T. 2½" th. Mg.				
Covering and application List	Months Required....	2.7	2.0	1.6	1.4	1.2	2.8	1.8	1.4	1.2	1.0	2.1	1.6	1.3	1.0	0.9
	Saving per year.....	5.76	7.73	9.72	11.72	13.70	6.61	8.88	11.14	13.40	15.67	7.57	10.15	12.72	15.32	17.88
Covering and application List—20%	Months Required....	2.2	1.6	1.3	1.1	0.9	1.9	1.4	1.1	1.0	0.8	1.7	1.3	1.0	0.8	0.7
	Saving per year.....	5.80	7.77	9.76	11.76	13.74	6.65	8.92	11.18	13.44	15.71	7.61	10.19	12.76	15.36	17.92

determine the cost of steam for his particular case and the approximate cost of the covering in terms of the list price. If these costs do not correspond with those given in the tables, it will be necessary to interpolate. The main object is to convince the engineer of the large savings that can be accomplished.

The tables show the time required to repay the original cost of the covering and its application, and also the savings in dollars per year per lineal foot of pipe and per sq. ft. of flat surface, for various temperatures and pipe sizes. In computing the tables a high temperature material and 85 per cent. magnesia have been used as the insulation. The most economical thickness has been used for the average of the steam costs assumed and the thickness of the inner layer has been chosen so that the temperature at the inner surface of the magnesia next to it will not exceed 550 deg. fahr.

The thicknesses used in these tables can safely be used for other insulations having approximately the same conductivity and can be considered as standard practice for superheated steam temperatures, as they have been worked out on a scientific basis and also in accordance with the standard thicknesses of coverings as manufactured for the different pipe sizes.

"Engineer" Defined

"The engineer is a man or woman of professional training or experience who applies engineering principles to research design, construction, operation or production, or who imparts technical instruction in these fields. The professional engineer must be carefully differentiated from the machine or engine operative."

An A B C Principle in Air Conditioning

On April 27 on the streets of Chicago the temperature was 84 with a high degree of humidity. Pedestrians were mopping their faces. In calling at various offices in the well known loop district in Chicago it was found that in every office the windows were wide open and the occupants were sweltering in 84 degree highly humid air.

This was the condition in all of the offices except one. Upon entering one office, the caller noticed at once a different condition. There was a decided coolness in the air. Upon investigation it was found that the temperature was 72 degrees.

"How does it happen that your offices are so cool and pleasant?" was the question asked of the man at the desk, who, by the way, was E. P. Heckel, vice president of the Carrier Engineering Corp. "Do you have a cooling system in this building?"

"No," he replied. "We have no cooling system and the cool air in this office is due to a principle in air conditioning which is as simple as A B C. Walls and windows, which keep out the cold in winter, will also keep out the heat in summer. You will observe that the windows in these offices are all closed and that the air in them is quite comfortable. But what would happen if we pulled a lot of outside 84-degree air through ducts and distributed it throughout the offices? It would then be 84 degrees in the offices as well as outside.

It is frequently possible for offices to be kept cool and comfortable for a limited time in this manner on a hot day, after a protracted cool spell of weather, but this is a practice that the human race never seems to learn.

A. S. R. E. Discusses Windowless Skyscrapers

IN a recent meeting of the American Society of Refrigerating Engineers, the New York of the future with its thousands of offices, buildings, homes, hotels and theaters was visualized as completely windowless.

Declaring that the only use for windows "is to look out of them," Dan C. Lindsay, former expert in the Bureau of Standards in Washington, painted the picture of the windowless city.

Mr. Lindsay said that it was quite within the realm of possibility that a trend already noted in the use of air conditioning systems in large hotels and theaters might result in the construction of many windowless buildings within the next ten years.

It was reported that the American Telephone and Telegraph Company was planning the construction of a $1,000,000 windowless building for its transcontinental lines, either in New York or in Boston.

Mr. Lindsay told the engineers that electric lamps could supply as good light as the sun in the interior of the homes and skyscrapers and that the great fans used in the ventilating system of many theaters could supply more and better fresh air than that which enters now through windows.

He said that buildings without windows would cost less to construct, and that by extending them below the level of the ground much needed space could be saved. The windowless building, he said, would be easier to heat in winter and easier to keep cool in summer.

"Good artificial light is much better than poor daylight or a combination of daylight and artificial light," he declared. "The central heating systems now employed are less than 20 per cent efficient because the windows in buildings allow the warm air to escape," he said.

Mr. Lindsay pointed to the Woolworth and Equitable Buildings, the first with its 2,500 and the second with its 5,500 windows, as examples of useless extravagance. He asked the engineers to consider the cost of washing these and the money that could have been saved in construction cost had they been built in solid brick.

Mr. Lindsay said that, in addition to supplying better light and maintaining a satisfactory temperature, the air conditioning system in windowless buildings would keep out the city dust.

Mr. Lindsay stated that the only problem remaining to be solved was a psychological one. He pointed out that sufferers from cloisterphobia exist and that life would be extremely miserable to them without windows. He suggested that ultra-violet rays might be furnished in small quantities to add to the benefits of artificial light.

In Industrial Plants

Heating and Process Loads

Determine Economy of Live or Exhaust Steam

By A. R. Acheson

THERE are numerous industrial plants in which live steam is being used for process work and for heating buildings where exhaust steam from engines or turbines might preferably be used. Each plant requires separate investigation; there is no fixed rule which settles the question whether live steam should or should not be used. Some of the factors which enter into the case may be brought out by following through the method used in investigating an existing plant for which the data given below are applicable.

The first thing to do is to prepare a set of steam load curves, showing the amount of steam used for process work and for heating buildings. Fig. 1 gives typical curves for the case in question, showing the average monthly loads expressed in boiler horsepower and in thousands of pounds of steam per hour. The preparation of such curves requires a careful study of the actual conditions prevailing at the plant, special note being made of the variation of the loads during the day and during the different seasons of the year.

Checking the Loads

The loads are ascertained in several different ways—in fact, usually by a combination of different methods. If the various steam loads are separately metered, the task is easy, but too often no meters are available and the investigating engineer must resort to tests and calculations. Actual tests are much more satisfactory than mere calculations and should be made wherever possible.

Where the condensate can be recovered the simplest emergency test is to trap the returns from the process or building being investigated to some measuring barrels or tanks. In general measuring tanks can be used accurately enough and actual weighing is not necessary.

Where the condensate is not recovered, some form of steam meter or orifice should be used. If conditions do

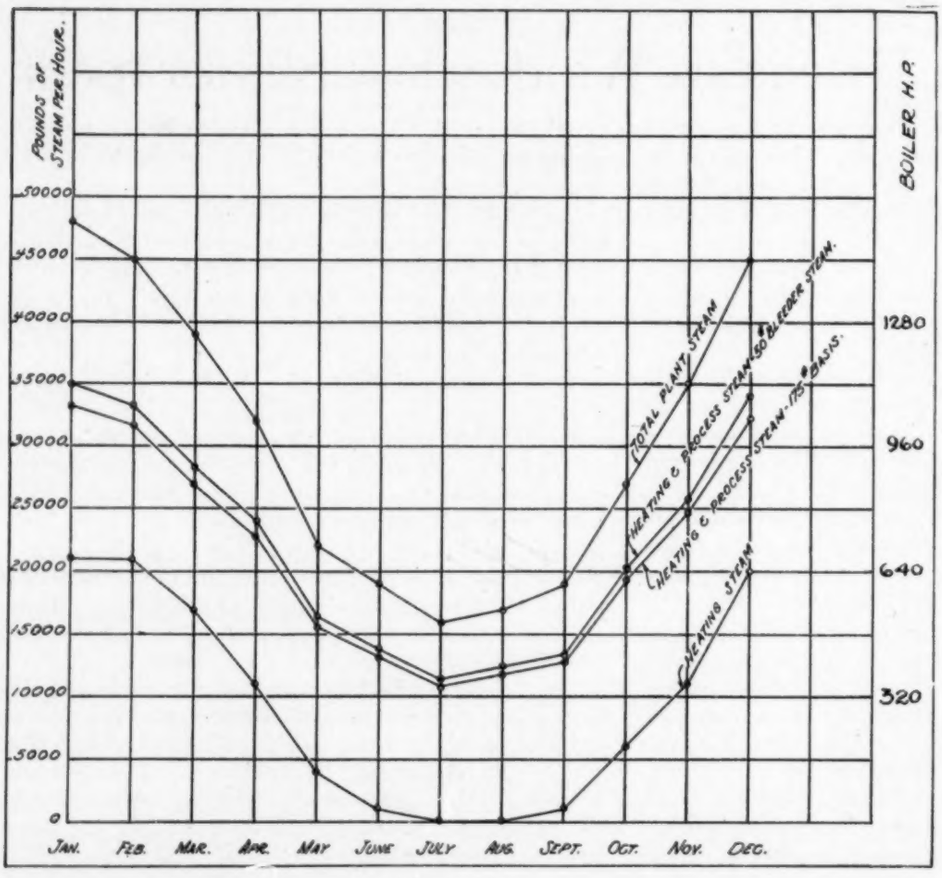


FIG. 1.—LOAD CURVE FOR HEATING AND PROCESS STEAM

not warrant the installation of this equipment for temporary use, data close enough for the purpose may be obtained by using a valve of known opening, preferably calibrated by a preliminary test, and taking readings of the pressure on each side of the valve at various loads, with a proper record being kept of the time element. The pressure drop in a known length of pipe of given diameter is a useful clew, at times, to the flow that is occurring.

The delivery of boiler feed and return pumps should be noted and checked against computations and tests of steam flow. Too much emphasis can not be placed on the value of this cross-checking, as meters are known to go wrong and errors creep in unasked only too often.

Where it is necessary to separate heating and process loads, and where records of total loads only have been kept, a search will often reveal a period during which building heating alone was done, and so the process load can be computed by noting the reduction from the usual load. This method then will act as a check on other computations and tests.

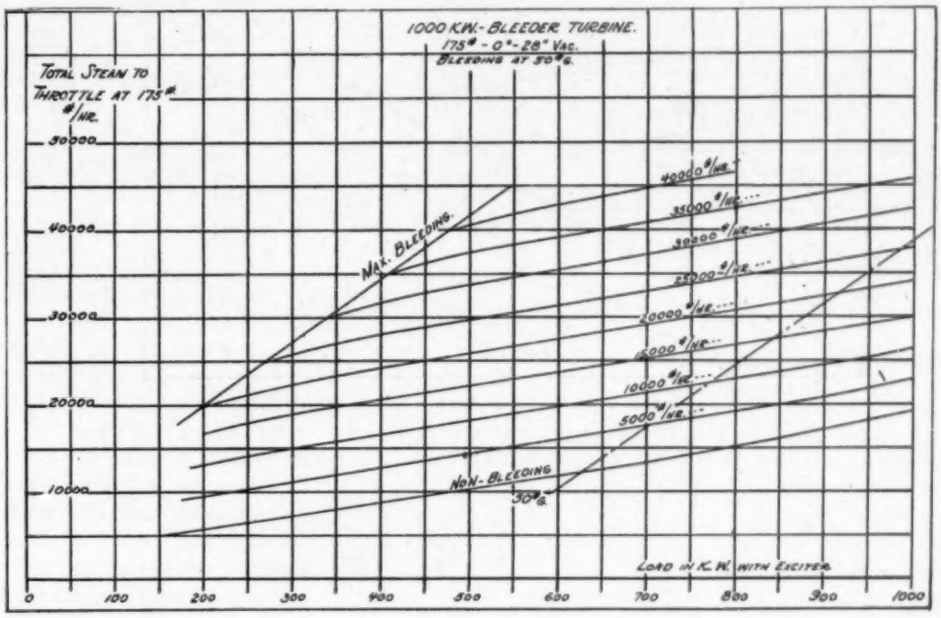


FIG. 2. — BLEEDER TURBINE STEAM

Estimates of heating loads based on the cubage or square foot of floor bases are worthless except for exactly similar buildings, similarly located. In each case, proper allowance must be made for the type and excellence of construction of the building, air tightness of window frames, location and number of ventilators, wind and sun exposure, presence of heat generating and circulating equipment, requirements regarding steady or intermittent heat, opening of doors, temperature to be maintained, etc. If proper consideration is taken of these and similar factors the straight heating load may be calculated using the degree day method.

For process heating frequently accurate results can be obtained by computing the heating and drying actually done, with proper allowances for radiation losses and for vapor carried off. These methods should always be used as cross-checks on the meters.

Throughout it is advisable to reduce all steam quantities to the same basis, preferably to equivalent from and at 212 deg. fahr. or to equivalent steam at boiler pressure.

In an actual investigation, instead of there being a single set of curves, as in Fig. 1, there will be a series of similar curves for different seasons of the year and for different times during the day.

Computations for Specific Plant

The computations hereinafter described will apply to the one set of curves only, Fig. 1, but the method would apply equally well to a series of curves. For the actual case being considered the loads happened to be very uniform, and the single set of curves applied with only slight modifications.

The boilers available were good for 175 lb. gauge pressure and had no superheaters. The maximum pressure required for process work was 50 lb. gauge; for heating work 5 lb. gauge. For these conditions a bleeder or extraction turbine was considered.

Fig. 2 gives the total steam admitted to the turbine when bleeding the stated amounts of steam at the stated loads. Water was available for condensing purposes and so a condensing type turbine was considered. The curves given apply to a particular type of turbine only and for the pressure given only; turbine manufacturers gladly supply interested parties with curves covering their particular requirements.

Table 1 gives data computed from the load curves, Fig. 1, and steam curves, Fig. 2. A typical set of computations is herewith given. For the month of January, the heating and process load, from Fig. 1, averaged 33,300 lb. of steam per hour at 175 lb. gauge, no superheat, dry steam. Steam, in passing through the high pressure part of the turbine to the bleeder valve, gives up some of its heat, and if the steam is dry at admission it will be slightly moist at the point of extraction. The Mollier diagram affords a ready means of arriving at the quality of the steam bled. Fig. 3 shows a Mollier diagram simplified to show the method. For actual computations use a large chart, a very useful copy of which may now be obtained from the Engineering Society headquarters.

Quality of Steam

On Fig. 3, point *A* represents steam at 175 lb. gauge and dry. The heat to form one pound of this kind of steam is found by squaring over to the point *D* and is found to be 1197 B.t.u's. The vertical line *A-B* represents the expansion of the steam down to the bleeder valve at 50 lb. gauge. Square over to *E* and find 1109 B.t.u's. as the heat per lb. of steam at the end of expansion, provided there is no friction in the turbine blading and nozzles.

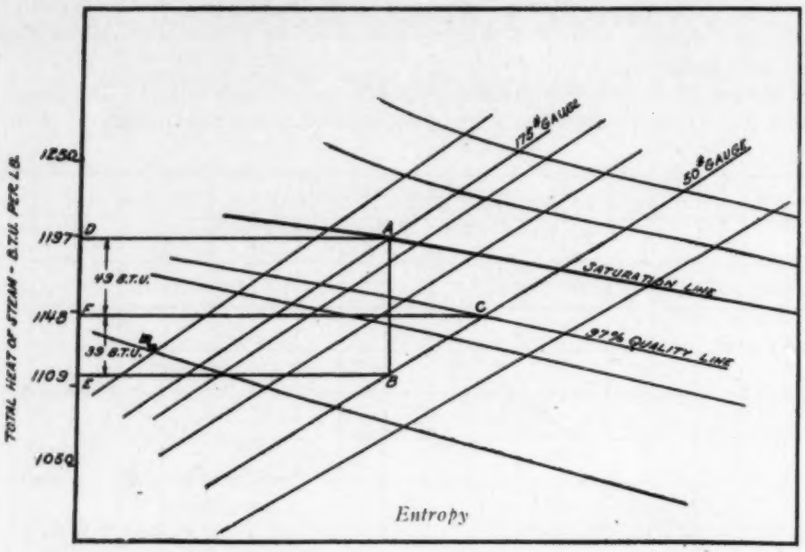


Fig. 3. Mollier Diagram

For the turbine considered there is friction, and about 45 per cent of the difference between 1197 and 1109, that is, of 88 B.t.u's., is returned in friction heat. This practically occurs at the lower pressure, 50 lb., and the heat of the bled steam is then 1148 B.t.u.'s. Square over horizontally from *F* to the 50 lb. pressure line which is cut at the point *C*. The quality line passing through *C*, in this case the 97 per cent line, gives the quality at the point *C*.

This is the quality of the steam actually bled off the turbine at 50 lb. gauge—showing that it is commercially dry steam.

If, as is often the case, and would be the case in a new plant, superheated steam is admitted to the turbine, steam still superheated may be bled off the turbine. The superheat can be read off the Mollier diagram in the same way as just explained for steam saturated at admission.

Fig. 2 shows that when the turbine is carrying a load of 800 k.w., and 35,000 lb. of steam are being bled off at 50 lb. gauge, then 42,700 lb. of steam must be admitted through the turbine throttle. The difference between 42,700 lb. and 35,000 lb., namely 7,700 lb., is the steam that passes per hour to the condenser. This residual steam is chargeable against the cost of the power generated, but in addition the heat extracted from the bled steam on its way from the throttle valve to the bleeder valve must be added.

The Mollier diagram, Fig. 3, shows that 49 B.t.u's. are so extracted per pound of bled steam. The heat extracted prior to bleeding is therefore, 35,000 × 49 = 1,715,000 B.t.u's.

Steam Chargeable to Power

The heat of formation of each pound of live steam admitted to the turbine was 1197—heat in the feed water at 202 deg. = 1197 — (202-32) = 1027 B.t.u's. Hence, the heat extracted for generating power prior to bleeding is equivalent to 1,715,000 ÷ 1027 = 1670 lb. of live steam at 175 lb. Add 1670 to 7700, the residual steam that passed the condenser, and obtain 9370 lb. as the total equivalent live steam chargeable to power generation. Divide 9370 by 800 and get 11.70 lb. of steam per k.w. hour chargeable to power, as given in column 6, Table I. In a similar manner the remaining data in Table I were computed.

The average is found to be 14.30 per k. w. hr. To allow for auxiliary steam add 5 per cent and obtain 15.0 lb. per k.w. hr.

Assume a modern boiler plant using pulverized fuel and an evaporation of 10 lb. per steam from 202 deg. fahr. and at 175 lb. pressure per lb. of coal. The coal would then be 1.5 per k.w. hr. Assume coal at $6.00 per ton crushed and fired, the cost per lb. is .3c and the coal per k.w. hr. would be 1.5 × .3 = .45c per k.w. hr.

Installation and Operating Costs

The installation costs are listed as follows:

Item		
1.	1—1,000 k.w. turbo-generator 175 lb. extraction at 50 lb. condensing at 28 in. vac.	$25,000.00
2.	1—condenser for full 1,000 k.w. plus pumps and motors	9,500.00
3.	Piping, erection, foundations, special valves, frt.	8,900.00
4.	Electrical switchboard and electrical changes	4,000.00
5.	Condenser water piping	10,000.00
6.	New turbine room	12,000.00
7.	Miscellaneous	5,000.00
		$74,400.00

Naturally, these items will vary greatly with the local conditions. Items 5 and 6 may sometimes be very small.

The annual cost of operating the bleeder turbine to develop a steady load of 800 k.w. for 24 hours a day, 300 days a year would then be as follows:

Annual cost of coal—800 × $.0045 × 24 × 300 =	$25,920.00
Additional labor and supplies	5,400.00
Fixed charges on $74,400 @ 14 per cent	10,416.00
	$41,736.00

Total k.w. hrs. per year, 5,760,000.
Total cost of bleeder turbine power = .74c per k.w. hr.

1.12c per k.w. hr. would be a low price for purchased

electricity for a plant of the size being discussed. At this rate, the 5,760,000 k.w. hr. per year would cost $64,500 per year. The annual net saving would then be $64,500 — $41,736 = $22,764, which is a net return of 30.6 per cent on the total investment of $74,400.00, net after paying all carrying and operating charges.

Naturally other possibilities have to be given proper consideration. The analysis would include consideration of using non-condensing units instead of the bleeder condensing type. Uniflow engines and high pressure turbines (400 lb. and up) would naturally be considered. Much would depend on whether or not new boilers have to be installed, whether condenser water is available and the duration of the load during the day.

TABLE I—STEAM CHARGEABLE TO POWER GENERATION BY A BLEEDER TURBINE

(1) Month	(2) Load on Turbine, Kilowatts	(3) Steam Bled at 30 lb. Lb./Hr.	(4) Total Steam to Throttle at 175 Lb., No Superheat Lb./Hr.	(5) Steam to Condenser at 28 In. Vac. Lb./Hr.	(6) Equivalent Steam at 175 Lb. Power Only Lb./KW Hr.
Jan.	800	35000	43000	8000	11.7
Feb.	800	33200	41300	8100	12.1
Mar.	800	28300	37200	9100	13.1
Apr.	800	24000	34100	10100	14.1
May	800	16300	28000	11700	15.6
June	800	13800	25900	12100	15.9
July	800	11400	24100	12700	16.5
Aug.	800	12400	24900	12500	16.4
Sept.	800	13500	25800	12300	16.2
Oct.	800	20300	31200	10900	14.8
Nov.	800	25800	35500	9700	13.6
Dec.	800	34000	41700	7700	11.6
					12) 171.6
				Average	14.3 lb. per KW hour

Possibilities of Exhaust Instead of Live Steam

This particular analysis drives home the fact that under favorable conditions bleeder turbines can generate power exceedingly cheaply, and owners of factories now using any considerable quantity of live steam for heating and process work should investigate the possibilities of these and similar units which can provide exhaust steam to do the work now being done with live steam. Each plant is individual and turbines are available for all pressures, and, if necessary, steam can be bled off from the same turbine at different pressures to suit the plant requirements.

Heating Systems Suitable

When considering spending funds to rehabilitate an old plant by arranging to use exhaust steam instead of live steam, the time is often appropriate for making changes in the existing heating system to reduce the amount of steam used for the same heating effect previously obtained.

One of the first considerations would be the advisability of adopting the zoning system of heating in which the amounts of steam supplied to each zone are controlled independently of each other, according to the specific need of each. The simplest way is to use hand operated valves for each zone, but automatic adjustable pressure reducing valves are available. Another step in advance is to control these reducing valves by a thermostat located in a suitable place in each zone; suitable, because the location of the thermostat must be carefully chosen. Another method is to control the steam supply to the zone according to the prevailing outside temperature. A suitable thermostat placed outdoors controls the steam pressure for its zone and, thus, the heat supplied varies according to the outdoor temperature. Proper arrangements are made for quicker heating during "warming up" periods.

In all these methods the radiation in the zone must be properly balanced and the piping sizes properly chosen so that heat is uniformly distributed when steam at varying pressures is admitted to the zone.

Another method is to control the temperature by controlling the vacuum in the heating system. This is done automatically by means of either an indoor or outdoor thermostat. The lower the temperature of the radiator, the less overheating there is at the ceiling of the room. It has been demonstrated that, by keeping radiator temperatures low and radiators low, the cost of heating has been reduced 20 to 40 per cent. The cost of equipment to give zone control is relatively low and the savings may pay for the equipment in a very short time.

The same idea of better control applies equally well to process heating, where today vast quantities of heat are wasted by the use of excessive pressure.

Proper use of exhaust steam and proper control of the heating and process equipment can work wonders in reducing the cost of heating in industrial buildings.

In all such considerations as the foregoing, the fact that heating is a necessary part of a manufacturing process must never be overlooked. Without heat for buildings or process the factory may have to be shut down. Accordingly, the engineer must always provide capacity to function first, and then but not until then, endeavor to secure highly efficient operation. Capacity first—efficiency second.

Weld Bronze Condenser Head

Under ordinary conditions preheating is not necessary in bronze welding. Here, however, is an instance where preheating was necessary.

The head of the condenser used in the refining process in a plant of a starch refining company suffered an 18-inch break. It was necessary that it be repaired or replaced at once in order to avoid loss of time and money. The casting was an intricate one and would have been costly to replace. The plant welder was called in, and after examining the nature of the break, decided that it could be bronze welded by first preheating it.

A furnace of loose fire brick was built up. The condenser head was placed in the center of this temporary preheater, the base of the piece resting on two six-inch pipes. The next steps were to clean the crack thoroughly with a stiff wire brush and prepare and light a charcoal fire under the casting. An asbestos paper covering was placed over the job and the entire casting was allowed to come to an even temperature. Bronze welding was then begun. A standard high grade bronze rod was chosen and a good quality of flux was used.

Low Humidity Drying

By Malcolm C. W. Tomlinson

Article No. 1

MANUFACTURERS of electrical equipment have always faced the problem of moisture removal from hygroscopic materials used for insulation. In the earlier days of the electrical industry it was not unusual for rejections, due to this cause alone, to run into high percentages of actual production.

Vacuum methods of drying have greatly reduced the proportion of such rejections but have not solved the problem. During periods of high humidity weather, production and inspection are still seriously hampered. Furthermore, the range of variation in electrical characteristics of the finished product is much too wide. Manufacturers realize that when this range is reduced it will be possible to obtain satisfactory results with less expensive insulation and at lower labor cost. The latter expectation should be realized on inspection costs alone.

Moisture Elimination by Air Conditioning

Research and development work, in the past five years, have not only shown how to obtain better control of moisture elimination in insulation by the use of air conditioning at very low humidities but have also provided ways and means for the accurate determination of the moisture in air, under such conditions, and have furnished an amazing amount of information on human comfort.

Recent information on other investigations indicates that another new low humidity field is opening in hospitals and sanitariums where lung diseases are likely soon to be treated by means of this form of air conditioning.

In discussing the application of low humidities not only to manufacturing but also to testing and operating, only elementary thought will be presented. The adaptability of low humidities to various phases of the electrical industry will, of course, vary to a considerable extent. Each manufacturer will have to experiment somewhat to determine whether ½ per cent or 10 per cent relative humidity is nearest to the condition he needs and also what temperature is likely to fit into his operations best. Therefore, most manufacturing establishments will find themselves face to face with the necessity of setting up standards of their own.

This particular article will be primarily concerned with moisture removal. In articles to follow, human comfort at low humidities, measurement of moisture in air at low humidities and the installation of equipment to obtain low humidities will be discussed in succession.

Vacuum and Atmospheric Drying

Vacuum forms of drying have been known and practiced for many years in the electrical industry. It is probable that in the lamp industry, vacuum drying has been carried to its highest present stage of perfection. Atmospheric forms of drying are also used, to somewhat less extent, for electrical purposes. Air conditioning at lower humidities is really a highly specialized form of atmospheric drying since it employs air washers, baudelot coils and radiators for cooling, cleans the air of dust and dirt by means of the washers, often automatically controls the amount of air admitted from the outside for mixing purposes with the recirculated air, provides room pressures, air motion and temperature to suit the requirements of each particular problem and refrigerates the cooling mixtures needed.

In the earlier days of this industry, everyone remembers the air conditioned movie theater which was actually so chilly in hot weather that the reaction of the human body, when one left the theater, was almost violent. Now, with a vast amount of knowledge on comfort available, this type of air conditioning has largely vanished.

Holds Regain at Fixed Point

The main advantages in low humidity air conditioning, from a drying standpoint, are found in the fact that it is possible thus to hold the regain of moisture, by hygroscopic materials, whether of vegetable, mineral or animal origin, at a fixed point.

As an example, suppose certain goods are to be

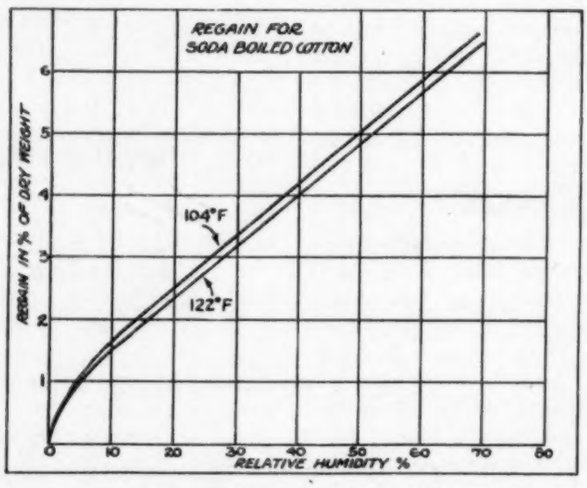


CHART SHOWING REGAIN CURVES OF URQUHART AND WILLIAMS

dried by vacuum to within ½ inch of the absolute pressure at a temperature of 370 deg. fahr. under conditions which assure that the moisture handled will not exceed 1 per cent of saturation. At atmospheric pressure the moisture in a saturated air-water-vapor mixture, at 370 deg. fahr., is found to be 34.48 lb. per lb. of dry air by reference to Goodenough's tables for steam and for air-water-vapor mixtures.

Then, by Boyle's law of partial pressures:

$$\frac{P_v}{P_a} = \frac{28.8\ W_v}{18\ W_a} = \frac{1.6 \times 34.48}{100} = 0.5517 \text{ lb. per sq. in.}$$

$$\frac{P_a + P_v}{P_v} = 1 + \frac{P_a}{P_v} = 1 + \frac{1}{0.5517} = 2.813 \text{ lb. per. sq. in.}$$

$$P_a + P_v = ½ \times .4912 = 0.2456 \text{ lb. per sq. in.}$$

$$P_v = \frac{0.2456}{2.813} = 0.0874 \text{ lb. per sq. in.}$$

$$= 4.52 \text{ mm Hg. or } 31.7 \text{ deg. fahr. dew point}$$

where P_v = partial pressure of the water
P_a = partial pressure of the air
W_v = partial weight of the water
W_a = partial weight of the air

This dewpoint is equal to 26.12 grains of moisture per pound of dry air. In other words, this condition is actually equivalent to 5.4 per cent relative humidity at a dry bulb temperature of 115 deg. fahr.

From the above data it can be seen that drying by vacuum, under the above conditions, has the advantage of a saving of time, as usually it can be done in a third of the time required for materials to be dried by low humidities. Furthermore, the temperature used for the vacuum example is as high as is safe for some forms of insulation and the system which must hold ½ inch absolute requires somewhat more than ordinary supervision to maintain. In addition, many insulated parts and devices which are vacuum dried are not impregnated under vacuum. With such conditions, unless a room conditioned at a proper relative humidity is located adjacent to the vacuum driers, it is almost certain that there will be some regain of moisture before seals can be applied.

The problem of regain after vacuum drying presents the greatest difficulty in this method of drying. Suppose that an insulation of soda boiled cotton, 0.05 inches thick, must be dried. If reference is made to the regain curves of Urquhart and Williams, shown in the accompanying illustration, it will be possible to see that a regain of from 1 to 5 per cent of the dry weight can be expected where the shop atmosphere, surrounding the vacuum driers, ranges from 20 to 60 per cent relative humidity. With thin insulation the pickup is likely to be very quick.

Possibilities of Low Humidity Drying

The examples furnished may not be as representative as could be desired but they serve to illustrate the possibilities of low humidity air conditioning.

There are a number of fields, as has already been partially pointed out, where this method of drying is practicable. One is as a protection against regain following vacuum drying. Another is as the sole drying method where time is not so important. A third is as the main drying agent, at very low humidities, with vacuum drying as the auxiliary. The fourth is as a protection against electrical leakage for inspection and testing floors. The fifth is as a protection against electrical leakage for sensitive operating equipment which employs very low voltages and currents.

The method proposed is, therefore, suitable for use in overcoming two direct effects of the presence of moisture in or on a dielectric. One is the lowering of the insulation resistance. The second is leakage. Indirectly an improvement in these characteristics means an improvement in capacity.

Some New Methods of Steam Heating

IMPROVEMENTS in heating systems that concern themselves with district heating naturally refer, first, to the use of steam in what are known as vacuum steam systems, and, second, to the controlled distribution of the steam throughout these systems.

The partial vacuum in moderate-to-large steam heating systems has always been produced by some sort of pump or ejector on the far end of the return mains. The amount of this vacuum is adapted to the outside weather conditions and in compact isolated plants may be maintained as high as 20 inches of mercury without difficulty. In addition to the vacuum in the return mains, which is common to all vacuum systems, radiator steam may be used in either of two ways: (1) low pressure steam admitted in such quantities as to heat a part of the radiator surface to the steam temperature, the remaining part being comparatively cool; (2) heating all the radiator surface, but with steam at a partial vacuum (somewhat less than that within the return main). Top connected, hot water type radiators are always used. Fractional heating within the radiator, therefore, is always from the top toward the bottom of the radiator.

Distribution within the supply mains and branches is accomplished by means of pressure regulating valves and orifices. Steam to the radiators is controlled by hand valves and orifices. Return condensation and air are taken off through thermostatic traps. In all cases where differential vacuums are maintained in returns and radiators, thermostatic traps are necessary.

The latest developments in vacuum heating relate to the zoning of the system (the division of the system into units, each one of which may be independently controlled for conditions of sun, wind, occupation needs, etc.).

Vacuum heating and zoning may each be classed as economic developments. With the heat supply graduated closely to the needs of the respective rooms, there is less heat wasted by the occupants and there is a higher type of service performed.

The above is abstracted from an address by Prof. J. D. Hoffman, director of the department of practical mechanics, Purdue University, Lafayette, Ind., presented at the third annual district heating school held at that institution May 20-25, 1929.

Welding as applied to heating installations in Central Europe

By Konrad Meier

WELDING of piping was first tried to any extent during war times, when fittings were expensive and hard to obtain. The practice has been kept up ever since and is gradually being improved. It is now applied to installations of every size and contractors are getting their men regularly instructed. Like many other novelties, however, welding is used more or less indiscriminately and often outside its proper field, which fact is raising questions as to its merits.

Sufficient time has elapsed to show that properly welded piping will stand the ordinary strains from pressure and expansion. But a reliable joint is not all that must be demanded in heating work. From the engineering viewpoint it is also important that such a pipe system should give every assurance of delivery or performance. In this respect, the results

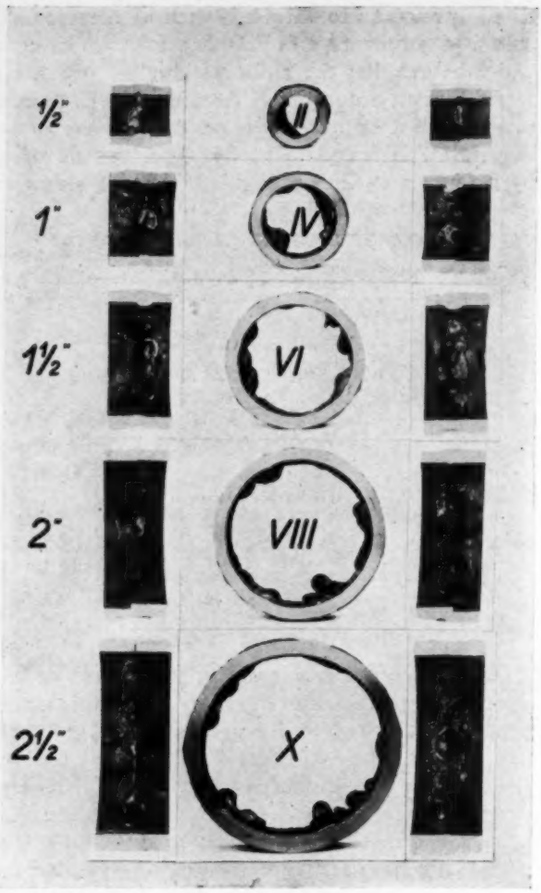


FIG. 1.—PHOTOGRAPHS OF WELDING PIPE ENDS, SHOWING THE RESULTS OF POOR OR INDIFFERENT WORKMANSHIP. THESE WELDS WERE TESTED TO DETERMINE THEIR RESISTANCE TO FLOW.

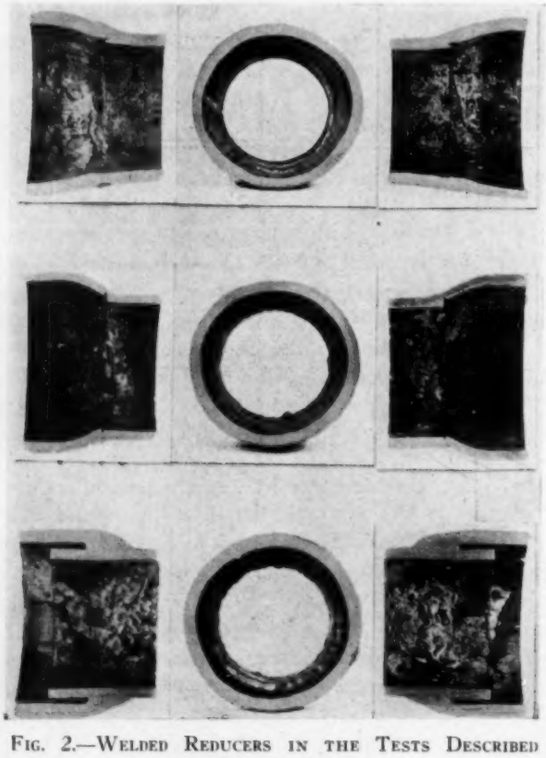


FIG. 2.—WELDED REDUCERS IN THE TESTS DESCRIBED IN THIS ARTICLE.

are not immediately apparent. Faults in circulation are often covered up by manipulation and other devices intended to make up for the lack of rational calculation. In any event, it would be proper to know whether the uncertainties of distribution are increased by welding and to what extent this method is really indicated and economical under present conditions.

To this end, extensive tests were carried through recently at the Swiss Federal Technical Institute of Zürich under the auspices of an industrial foundation. They were suggested and directed by M. Hottinger, consulting engineer and lecturer at the Institute, to whom credit should be given for the published data.* Inasmuch as no similar investigation appears to have been made in the U. S. A. so far, the results should be of interest to American engineers and contractors, even though allowances must be made for differences in methods of piping and the cost of labor. In Europe, for instance, mains of 2½ in. and over are generally made of lighter weight pipe, formerly put together with flanges and cast iron flanged fittings, while on branches and run-outs the pipe is bent to suit, whereas in American practice standard weight pipe and screwed fittings are

*Gesundheits-Ingenieur. Nos. 45, 49 & 50, 1928. No. 5, 1929.

used for a larger range of sizes with bent pipes and flanged joints for special situations.

Tests Compare Perfect and Average Welding

The tests were necessarily comparative. They cover perfect welding as well as such workmanship as must be expected from the average welder under conditions met on the job, since it would not do to calculate on the ideal, but rather on what may reasonably be expected. The resistance to the flow of ordinary screwed joints and fittings was tested by the same apparatus. All test pieces were inserted between lengths of straight pipe tested separately for friction, the amount of which was subtracted from the gross readings. These were obtained for different sizes and velocities. Special care was taken in determining these, as the factors of resistance are figured and expressed in terms of velocity $V^2/2g$.

Couplings

The joining pipe ends ordinarily are not counted as items of resistance. The factors, nevertheless,

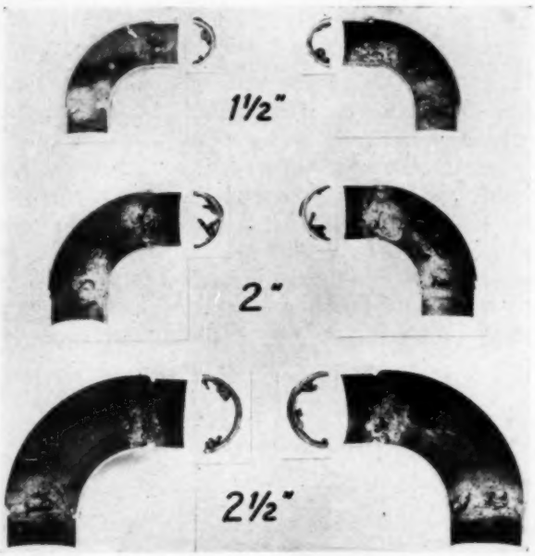


Fig. 3.—Ready Made Steel Pipe Bends Welded on. Note the Opportunities for Clogging.

were found to range from .5 to .05 respectively for ⅜ in. up to 2½ in. pipe screwed together in the ordinary way. For the welded butt joints illustrated (Fig. 1) the following figures were obtained:

Diameter	Welding Fig.	Factor of Resistance
½-in.	I	.12
½-in.	II	.42
1 -in.	III	.0
1 -in.	IV	.7
1¼-in.	V	.0
1½-in.	VI	.21
2 -in.	VII	.0
2 -in.	VIII	.16
2½-in.	IX	.0
2½-in.	X	.14

For small piping a welded joint, therefore, presents less obstruction to the flow, when perfectly made. With indifferent or poor workmanship the resistance is equal to or even larger than that of a fitting and may easily reach that of a short elbow. It appears to be an uncertain quantity for smaller piping in particular, while negligible as a rule for

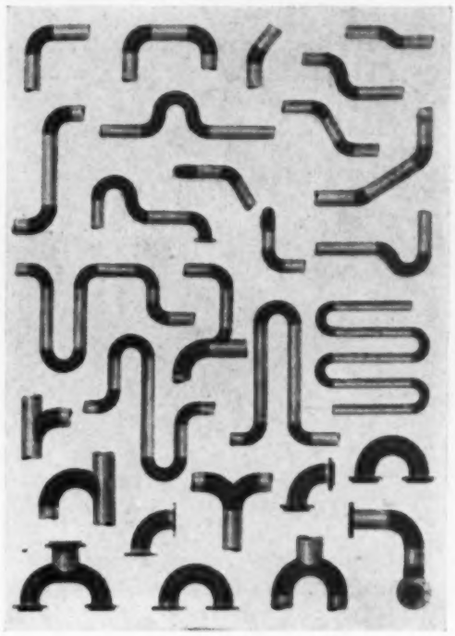


Fig. 4.—Ready Made Steel Pipe Bends.

diameters of 2 in. or 2½ in. and over. In Fig. 1 are shown views of the joints that were welded with indifferent or poor workmanship.

Nos. 1, 3, 5, 7 and 9 in the above table refer to perfectly made joints.

Reducers

Contractions of diameter, that were formerly effected by screwed reducers, are now often formed by welding. Tests were made with several sizes of fittings having ratios in area from 1/1.65 (2 in.-1½ in.) to 1/10 (1¼ in.-⅜ in.), the former showing factors of .08-.1 and the latter .37-1.0 for contraction and enlargement respectively based on the higher velocity. The tests for welded reductions were restricted to the most favorable ratio of 2 in.-1½ in. pipe. See Fig. 2.

Fig. 5.—Interior View of Some of the Welds Made in the Tests Described.

Direction of Flow	Kind of Reducer	Factors of Resistance For Smaller	For Larger
From 2-in. to 1½-in. pipe	Reducer Fitting	.21	.08
	Welded Reducer I	.13	.05
	Welded Reducer II	.21	.08
	Welded Reducer III	.35	.13
From 1½-in. to 2-in. pipe	Reducer Fitting	.27	.10
	Welded Reducer I	.15	.06
	Welded Reducer II	.32	.12
	Welded Reducer III	.37	.14

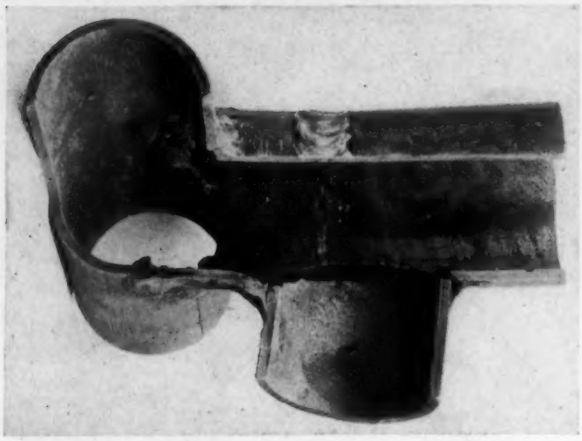


FIG. 6.—ANOTHER INTERIOR VIEW OF ONE OF THE TESTED WELDS

These figures show that welding may increase or decrease the resistance even for moderate changes in velocity, according to the perfection of the work. Evidently, for other ratios, where the process of drawing in and properly joining the pipe ends is less easy, the welding is likely to result in greater obstruction.

Elbows and Bends

These tests were extended to compare the resistance of fittings with that of bent pipe as well as that of ready made steel pipe bends welded on. They confirm that the factor varies with the diameter. It appears to be practically the same for the three methods, if the welding is perfect, but may easily treble for indifferently inserted and welded steel pipe bends, thus depending largely on workmanship.

Size	Kind of Bend	Factor of Resistance
1¼-in.	Long Sweep Fitting	.45
2 -in.	Long Sweep Fitting	.39
2½-in.	Long Sweep Fitting	.28
1¼-in.	Pipe Bent by Hand	.43
2 -in.	Pipe Bent by Hand	.36
2½-in.	Pipe Bent by Hand	.28
1¼-in.	Pipe-Bend Welded on (Fig. 4)	.45
2 -in.	Pipe-Bend Welded on (Fig. 4)	.36
2½-in.	Pipe-Bend Welded on (Fig. 4)	.28
1¼-in.	Pipe-Bends Welded on as	1.5
2 -in.	Shown by Illustration	1.0
2½-in.	(Fig. 3)	.74

It may be surprising that the pipe bent by hand presents the same resistance as the long sweep fitting in spite of the absence of joints. This is explained by the roughing of the inner surface through the process of bending, which materially increases the friction. Bent pipe, therefore, cannot be depended upon to ease the flow, unless smooth surface is assured. As might be expected, similar results were obtained for U bends and offsets. They confirm that we keep within the limit of errors when calculating them as multiples of the 90 deg. turn.

Tees and Intersections

It is known that the pressure losses in branch tees are largely dependent on the relative velocities in the joining runs, as well as on the shape of the fitting. These items of resistance are, therefore, uncertain at best. In the course of the investigation it became evident very soon that, with the uncertainties of the welding added, no figures could be given that would be at all reliable even for typical situations. And while the shape of the intersection may or may not be executed as intended, such figures could not be more than a rough allowance.

In theory, a welded breeching, when perfectly fashioned to suit the static and dynamic pressures in main and branch, as governing the rate and natural direction of the flow, would present the least and, in fact, quite negligible resistance. But these pressure conditions, even if considered by the engineer, are often ignored by the operator, and it may be too much to expect that in practice the theoretically best shape will be approximated. Breechings at an angle of 45 deg., for instance, are by no means always better than a take-off at right angle. And, besides, the angle is too often the resultant of local space conditions, accidents and whims. It would seem, therefore, best policy in the interest of reliable

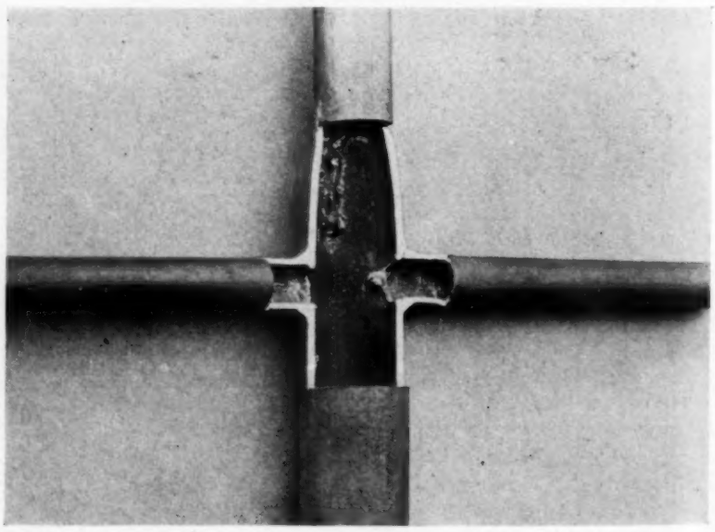


FIG. 7.—CROSS-WELDED IN ACCESSIBLE PLACE. COST OF 2-IN. RISER, EACH $1.50. RESISTANCE TO FLOW UNCERTAIN

work to adopt as a standard some clear-cut simple shape making for good workmanship, while paying more attention to pressure conditions in the sense of avoiding extreme changes in velocity as brought about by moderate losses of pressure.

Indeed, the investigation shows plainly that

wherever welding is considered, it becomes all the more important to calculate and design the distributing system with a view to making it least sensitive to these increased uncertainties. That this theoretical conclusion is supported by facts may be gathered from the experience of some leading contractors, which has brought about the practice of turning up all smaller branches in trumpet shape, thereby avoiding the uncertainties of sharp and deformed edges. While this is not the cheapest form, it is probably the most dependable one for small branches of larger mains.

Where mains are to be joined, the regular breeching is more appropriate, unless there is a decided difference in velocities. In any event, it is not advisable to attempt special shaping in the manner of tongued fittings, if only because the welder is not supposed to do any engineering, but simply to carry out the work as intended or planned, which should be done by rational calculation and design so as to eliminate the necessity of such devices and makeshifts.

On the whole, the tests indicate that welding, as done now, is of no advantage in forming tees and intersections on the job, since it cannot ease the flow as a rule, and present uncertainties are decidedly increased thereby.

Comparative Costs

In addition to the engineering side, the investigation also covered the question of economy. This was accomplished by systematic timing of the actual work involved by either method as a basis for calculating cost at current prices for labor and materials. An extract of the results is given here in which these two main items for the welding and the screwing operations are quoted separately for easier comparison with American conditions.

Both oxy-acetylene and dissous gas are used successfully for welding pipe work in Central Europe. The cost is about the same and the figures are applicable to both. As a rule, the butt joint is preferred and satisfactory, if sufficient space is left between contact surfaces for the material to enter. The time data are obtained for this type, as the V joint requires more preparation and is no longer considered necessary for reliable work.

As the co-operation of leading contractors was secured for this part of the investigation, the time represents that required by trained welders having experience in this particular field. The work was done under fair conditions. On the job it is likely to cost more, if paid for by the hour. The price assumed for the fitter or welder is 40c and for the helper 30c per hour, this being the average rate paid in Switzerland. In other European countries wages are generally lower. The cost of materials includes all fittings, packing, fuel for bending, gas, welding rod and usage of tools. No overhead expense is counted in either case. The totals, therefore, represent the net cost of making the joints and other features by screw fitting or by weld.

The observations and calculations were extended to a number of other fittings and their corresponding hand-made or welded shapes. The results only confirm the general trend, as shown by the selection given here.

It will be noted, that the ordinary screwed coupling is cheaper than the welded joint up to 2½ in. diameter. Likewise the screwed reducers. Reductions of more than one size are probably better made with fittings up to 3 in. or more, according to these figures. The bending of small pipe is shown to be advantageous, while elbow fittings cost about the same for the sizes from 1½ in. to 3 in. For this range, however, long sweep fittings cost more in Europe, but not as much as the ready made steel bends welded on.

For combinations of bends, the relative costs are practically the same. Ordinary reducing tees are usually made with two joints, while bull-headed tees

	Screwed Couplings			Welded Butt-Joints		
	Labor	Materials	Total	Labor	Materials	Total
½-in	.032	.036	.068	.18	.020	.200
¾-in.	.040	.048	.088	.18	.028	.208
1 -in.	.046	.062	.108	.18	.038	.218
1½-in.	.064	.122	.186	.23	.056	.286
2 -in.	.076	.174	.250	.29	.094	.384
2½-in.	.152	.286	.438	.35	.114	.464
3 -in.	.162	.446	.608	.35	.150	.500

	Screwed Reducers			Welded Reducers		
	Labor	Materials	Total	Labor	Materials	Total
⅜-½-in.	.038	.066	.104	.256	.020	.276
1-¾-in.	.044	.092	.136	.268	.028	.296
1½-1-in.	.056	.158	.214	.280	.038	.318
2-1½-in.	.070	.206	.276	.350	.058	.408
2½-2-in.	.144	.332	.476	.420	.096	.516
3-2½-in.	.158	.534	.692	.490	.114	.604

	Screwed Elbows			Bent Pipe*		
	Labor	Materials	Total	Labor	Materials	Total
½-in.	.032	.056	.088	.010	.014	.024**
¾-in.	.040	.080	.120	.014	.024	.038**
1 -in.	.046	.112	.158	.024	.040	.064**
1½-in.	.064	.224	.288	.180	.114	.294
2 -in.	.076	.320	.396	.262	.196	.458
2½-in.	.152	.562	.714	.452	.316	.768
3 -in.	.162	.868	1.030	.632	.430	1.062

* Without any welding.

**Bent in cold condition by one man.

	Screwed Bends			Pipe Bend Welded on		
	Labor	Materials	Total	Labor	Materials	Total
1½-in.	.064	.344	.408	.466	.328	.792
2 -in.	.076	.518	.594	.584	.430	1.014
2½-in.	.152	.948	1.100	.584	.548	1.132

	Screwed Tees			Welded Intersections		
	Labor	Materials	Total	Labor	Materials	Total
1½-1-1¼-in.	.084	.258	.342	.724	.136	.860
2-1¼-1½-in.	.098	.352	.450	.792	.178	.970
2½-1½-2-in.	.200	.626	.826	.958	.250	1.208
3-1¼-2½-in.	.220	.992	1.212	1.076	.316	1.392
3½-2-3-in.	.234	1.298	1.532	1.180	.402	1.582

	Screwed Tees 45 Deg.			Welded 45-Deg. Intersections		
	Labor	Materials	Total	Labor	Materials	Total
1½-1-1¼-in.	.084	.378	.462	.712	.144	.856
2-1¼-1½-in.	.098	.532	.630	.770	.188	.958
2½-1½-2-in.	.200	.866	1.066	.922	.264	1.186
3-1¼-2½-in.	.218	1.292	1.510	1.036	.332	1.368

generally require three welds. Hence, the screwed fittings for the former appear to be cheaper than the welded intersections up to 3-in. pipe and will compete with the latter for still larger sizes. The welding of intersections will, therefore, pay only on large mains and where no reduction on the run is necessary.

Branches leading off at an angle and likewise sweep tees are also less expensive than welds up to 2½-in., and regular breechings up to 3-in. diameter. The facts are similar in regard to crosses, even though the price of these fittings is relatively high. They cost less than welding up to 3½-in.

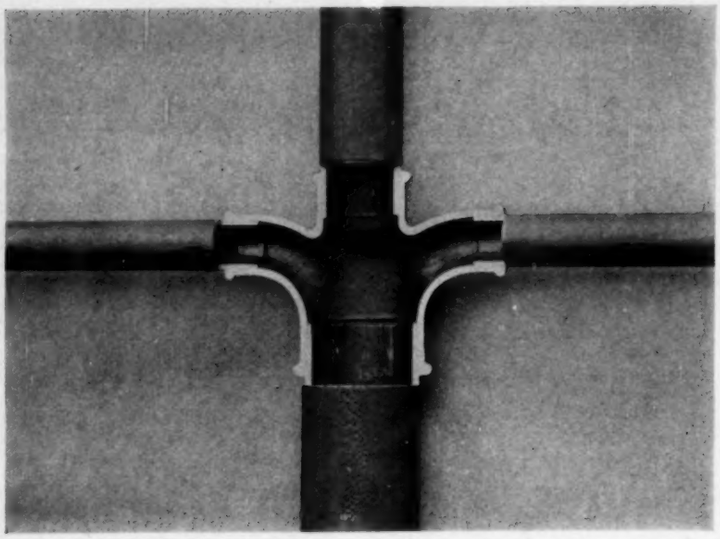


FIG. 8.—MALLEABLE SWEEP FITTING. COST OF 2-IN. RISER, EACH $.75. RESISTANCE FAIRLY WELL KNOWN.

The cost of welded intersections is clearly dependent on the number of welds required. The fitters often try to reduce it by shifting the changes in diameter to the end of a pipe length. The resulting deviations from the plans may or may not be material. But they do introduce further uncertainties in friction and resistances, which ought not to be encouraged. The figures given here are based on work properly done, but not on rounded neck branches.

The investigation also included welds on light weight steel pipe and a number of other shapes, thus covering a broad field and a great variety of cases. That the item of labor is certainly not higher than that to be expected in practice is borne out by another recent, though more restricted investigation carried out by the southern section of the German National Organization of Heating and Piping Contractors, which shows higher figures for the time required. It should be remembered that the cost of labor is largely a matter of individual skill. And this item, as the figures show, even at European wages, ranges from 95 to 70 per cent, whereas with the old mode of fitting it amounts to only 45 to 15 per cent of the total. Hence, the differences would be materially greater at wages prevailing in the U. S. A., which are from two to three times higher. Nor is it likely that the amount of work is in proportion to the wages. In fact, some of the time data published of late* appear to check closely with the figures obtained by Mr. Hottinger.

*John H. Zink.

Distribution of District Steam Lines

The most economical method of distributing steam in district heating systems is by means of trunk lines radiating from the plant to various points within the distribution area, according to W. W. Stevenson of the Allegheny County Steam Heating Co., Pittsburgh, Pa., in an address before the students of a district heating school held at Purdue University, Lafayette, Ind., May 20 to 25, 1929.

Yet this system does not provide for the element of growth when constructed of buried piping in the ordinary fashion. A more flexible system, Mr. Stevenson explained, consists of a gridiron design of mains to which steam is delivered through high pressure feeders from the plant. A third and rather distinct method is to install main lines in tunnels which form complete loops about the system. In these tunnels the size of pipes can be increased at will, and this design is most favorable to the location of additional plants at other points in the loop. Either of these latter designs, although costing slightly more than the first, are easily justified in preference to the first under appropriate local conditions.

The main portion of this talk had to do with the general principles of distribution system design applicable to all locations.

The effect of transmission pressure on the cost of the distribution system was discussed at length, starting with the variation in cost per unit of length, when a given steam line transmits a unit quantity of steam under all conditions from 1,000 lb. down to 5 lb. Graphs were shown indicating that, whereas this theoretical unit cost varied in the ratio of 1 to 6 when compared on the basis of steam properties only, the ratio decreased to the proportion of approximately 1 to 2 when all elements entering into the practical design of a system were considered.

One of the primary features of the design of a steam distribution system is, however, to allow for the element of growth in such fashion as to keep the piping investment somewhat in proportion to the quantity of steam distributed.

Watch Electric Wires in Welding

Neither oxy-acetylene blowpipes or any other open flames should be used around wires or equipment which are carrying electricity at high voltages. Heating gases or air increases the electrical conductivity. In the vicinity of high voltage current it is possible for sparks to jump to the blowpipe and result in injuries.

Air Circulation and Temperature in State Capitols

THE NATIONAL CAPITOL AT WASHINGTON, D. C.

By Samuel R. Lewis

A STATE CAPITOL building is a fearful and wonderful thing.

When this investigation was commenced, it was planned vaguely that some sort of tabulation of the condition of the various capitol buildings, as to ventilation, should be made.

The majority of the custodians to whom our inquiry was directed, however, considered a questionnaire an unspeakable nuisance, and filed ours in the waste basket.

We have, therefore, been compelled to eke out the few answers which were received with personal inspections, inquiries from friends, etc., until out of the forty-eight states and two territories we have information as to the capitols of twenty-nine of them.

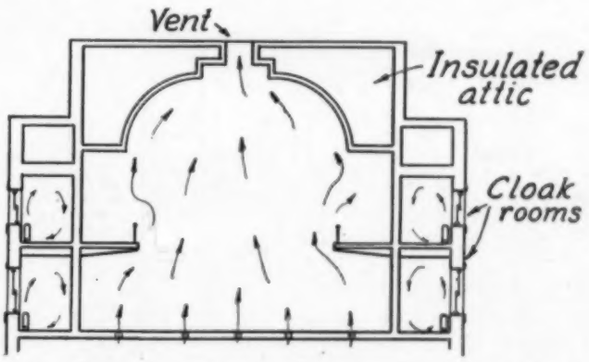
Many of the plants have been inspected personally.

Our conclusion is that there is little to be learned from a questionnaire, and that there is little about heating and ventilating to be learned by a novice, who, seeking education, hopes to gain it by inspection of state houses.

One strong impression persists as to the buildings themselves; that higher efficiency would be obtained from state funds if we could build for each state a beautiful monumental building purely to enlighten and astonish the folks—to give them a place to visit. It could be designed with beautiful facades and could be finished with rare marbles and woods. It could be built for all time, and could grow more valuable with the years. It could house fine paintings and sculptures. It would need no great elaboration as to heating and ventilating apparatus, except provision for easy access and renewal as the metals for pipes, ducts, etc., might, through the centuries, prove less enduring than masonry.

Then, in some easily accessible and less conspicuous part of the capitol city we would have a comparatively inexpensive and vastly more comfortable office building, dedicated to sunshine and to utility. It should be built like the latest office buildings, for a life of say twenty years, or slightly longer if obsolescence or increase of business shall not have overtaken it.

The legislative halls would be provided with theater-type, automatically controlled, air conditioning apparatus. Who knows but that in such an at-



IF THE ROOM HAS NO COOL EXPOSURES, THE AIR CURRENTS USUALLY WILL MOVE DIRECTLY FROM INLETS TO OUTLETS

mosphere we should find the making of better laws, more intelligently enforced by the executives, a matter of sequence?

To visit the "Cradle of Liberty" in Philadelphia, and to compare that airy, well lighted room of deliberation and debate with the usual gloomy state house legislative halls, gives one to think.

Beauty or Impressiveness More Than Comfort Influenced the Design of State Capitols

Tradition holds that the capitol building must be monumental—a place for inspiring awe at the majesty of government and for impressing the proletariat with the importance of its representatives.

All of the capitols, of which I can learn, were built by earnest workers who endeavored to build for all time, with massive walls and heavy footings, with brass and copper and even gold used lavishly for beauty and durability.

Many of the capitols were designed by architects who, being required to develop contacts with the political parties, had spent little time in development of art. It is a comfort and relief, therefore, to find the rare example of a capitol building which was not copied or inspired by the beautiful example at Washington. Most of these copies, like most other copies in life, pay tribute to the master hand of the original design by evidencing the crudity of the copyist. The foregoing may be taken to mean that, considering the architecture of state capitol buildings in the general average, I do not think so much of it!

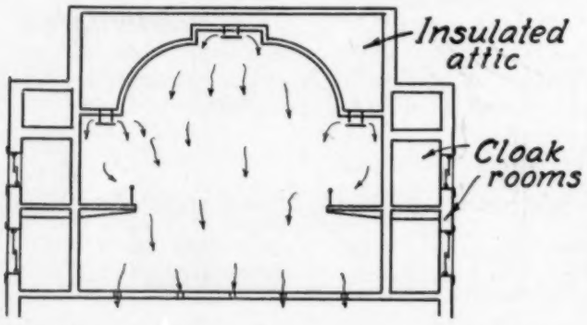
Almost always in these cases the architect has subserved utility and comfort for the inmates to a grand facade with which to impress the exterior on the countryside.

However, the new capitol at Olympia, Wash., while bearing the dome, seems to my eye to belong to the unusual class.

Offices have been in use for years in the Illinois capitol at Springfield in which the windows begin at the floor and run only part way to the ceiling, so that the exterior might follow some ancient tradition of symmetry. The feet of the occupants are their only members which see the sunshine.

The beautiful capitol at Madison, Wis., comparatively modern, cross shaped so as to get the maximum of light, already is outgrown, and many of the important departments are housed in rented commercial buildings.

The Ohio capitol at Columbus, said to be one of



Ideal Conditions for Air Circulation with a Mechanical Cooling Plant

The Illinois State Capitol at Springfield

the finest examples of its type of architecture in America, has an utilitarian annex behind it, and soon will have a modern state office building in the neighborhood.

Many of the state house buildings are well over one-hundred years old and some of them have additions and alterations which must have taxed the ingenuity of the constructors.

The capitol usually is in a park or square, with no very definite front door or back door, so that the heating is commonly provided from a remote plant, in order that coal and ashes may not litter up the state house grounds.

Many of the capitols are hoary with age and have survived several superimposed heating plants. This may be noted especially in the New Jersey capitol at Trenton, the most imposing facade of which features the chimney. At Trenton apparently they have decided to preserve the historic original structure, building more efficient buildings for active use not far away.

Due to the windowless assembly halls, many of the capitols have a mechanical ventilating apparatus, and must have it, both for heating and for cooling.

There exist today, in some of these buildings the best remaining examples of by-gone practice in the design and manufacture of ventilating equipment.

Each succeeding state house bore in its vitals when built, the latest and most effective apparatus that existed at the time of construction, provided

that apparatus survived the attenuating influences of political expediency.

Thus, among these buildings we may find veritable museum pieces, illustrating former ultra-modern heating and ventilating equipment. An inspection of the mechanical equipment of the New York capitol would be interesting from this standpoint to any heating engineer.

All capitols have assembly chambers, and nearly always these rooms, for the legislature and the supreme court at least, are of considerable size and are lofty as to vertical dimensions. Frequently, in the type which copies the capitol at Washington, the important legislative halls have few, if any, windows, but do have skylights. The unassuming hall which has enough windows for direct sunlight and fresh air is a rarity. As a rule, the various offices for the governor and principal officials are deficient in windows, or what windows they have are badly placed, and are ponderous to adjust and are leaky when closed.

The supreme court rooms are nearly all impressive,—many are beautiful, especially as at the St. Paul, Minn., capitol with its mural paintings.

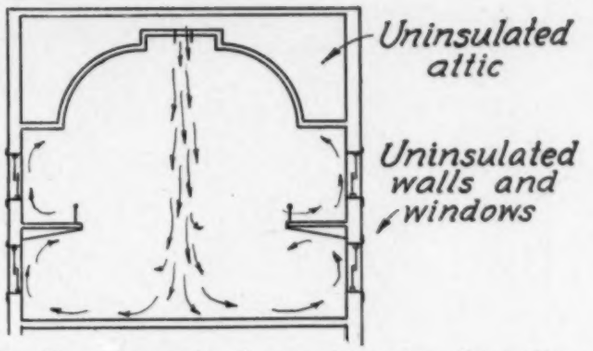
State Capitol Building at Olympia, Wash.

The houses of the legislature are usually less impressive in appearance. They are heavily inhabited when used at all, and as a rule, are miserably uncomfortable, smelly, drafty places of incarceration.

Every reasonably imagined method of heating and every reasonably possible point for fresh air introduction may be seen in these chambers,—side wall, upward, downward, rear, front and combinations and varieties of these; in some cases evidence being manifest that successive schemes have been tried. In one comparatively modern state house (twenty years is as yesterday to these buildings) there are great metal drums in the attic, which, something like a Corliss steam valve, by partial rotation may reverse the effect on the rooms of certain fans.

Heating in State Houses

As a rule steam is used for heating and nearly all the state houses have two-pipe vacuum systems of steam circulation.



The Heavy Coated Air Cascades Directly to Floor, While Warm Walls and Attic Causes Too Warm Conditions in the Higher Parts of the Room

I visited one beautiful and classic Greek temple, not long ago, and found an obsolete vapor steam system, for the direct radiators with high pressure steam engines for driving the fans and with steam driven pumps. Perhaps in the day when the plant was installed we had less confidence than we have now in vacuum traps. This building had wonderful vaulted crypts in its basement, comparable with the bombproof chambers of revolutionary time fortifications. It must have been no sinecure to get the supply and return piping through these massive walls and floors when they decided, many decades after the original construction, no longer to use the original fireplaces.

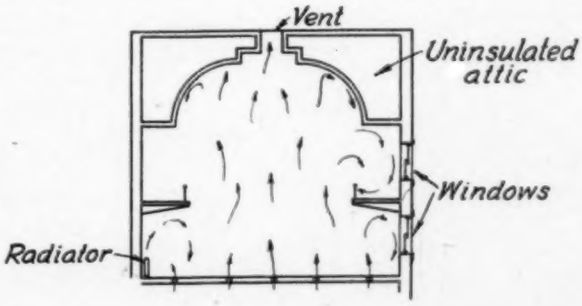
In those earlier days, the legislators were happy if they could keep warm. They didn't worry as much about keeping cool as do their present day successors.

The unit type of ventilating machine, which carries its own factory-built casing, with fan, motor, heater and means of regulation, is often in evidence in the air conditioning of some of the older buildings, and is giving good reports for itself.

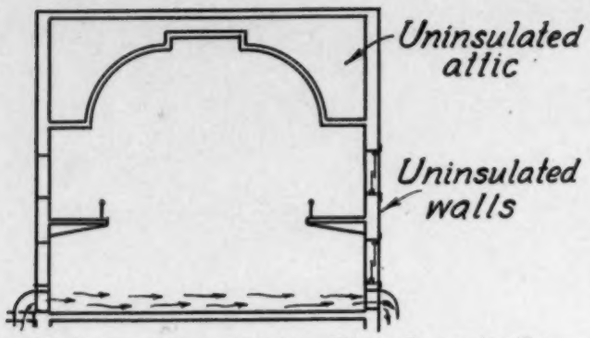
There is reported a decided tendency to use automatic temperature regulation and to keep it in repair, but despite this, with both the upward and downward systems of air introduction, many complaints of drafts are reported.

We find that in many cases these drafts were so serious that the ventilating plants were shut down. In many cases if the automatic control is properly adjusted and installed there need be no such draft-complaint.

One refreshing report came from Hawaii where "no heating system is necessary."



If the Room Has Outside Walls and Windows, and Radiators, the Air Currents Are Affected by These Conditions, and Ventilation Becomes Chaotic



BADLY DESIGNED COOLING SYSTEM. HEAVY COOLED AIR TRAVELS ACROSS THE FLOOR TO OUTLET WITHOUT AFFECTING ANYTHING BUT THE FEET AND LEGS OF OCCUPANTS

We have developed remarkably effective mechanical ventilating apparatus for the great picture theaters. The problem there is one of cooling the people rather than of heating them.

In nearly all problems of ventilation, the difficulty is well on its way toward solution as soon as the engineer can decide whether he has a heating or a cooling problem.

These modern picture theaters are nearly always surrounded by auxiliary rooms having independent heating arrangements. The attics or the roofs are insulated. There are no windows or skylights. Thus there are no undesirable local interior currents such as cool walls and windows, or heated radiators, always induce.

Air may be diffused evenly in such rooms at a temperature not greatly different from that of the room, and in such volume as gradually but positively to raise or lower the temperature without draft-complaint.

It is not strictly necessary in such protected audience chambers to limit the method of air delivery to any particular style, as upward, or downward, or side-introduction.

Ventilating Systems in State Capitols

There is, so far as I can learn, no state house legislative chamber exactly like a modern theater, since all have some attempt at sunshine. That is, if they are surrounded by galleries, cloak rooms and similar auxiliaries, they have skylights, and if they do not have skylights they are likely to have great, high windows, often provided with heavy drapes and curtains. As installed, the ventilating systems in these rooms deliver preheated air, warm enough to counterbalance the cooling effect of walls and windows, or direct radiators are provided in the rooms which attempt to care for the wall and window chill.

In the first type of plant, the lofty windows cause downdrafts on the people closest to them, while the people more distant get too warm. In the second type, the radiators often get too hot; then the air temperature is reduced to compensate, and the people feeling the cooler air, complain of draft.

Despite the best efforts of the operators, and despite the activities of those wonderful instruments of automatic temperature regulation, thermostats, we have complaints from the people. The ones with bald heads, the elderly, the nervous, are especially susceptible.

Insulation and Building Construction Important Factors in Heating and Ventilating

The solution to this problem lies along an unexpected line. It is to improve the building construction and insulation until in our hall we shall have a situation comparable to that of the theater.

The sources of wall-chill must be blocked off much as the dentist blocks off a nerve with cocaine. The wall and glass, then, no longer being much cooler than the air in the room, cease to pump down drafts of cool air.

For the same reason, we will no longer need direct radiators, the characteristic of which is to pump up jets of hot air, with a cold floor draft constantly in being to replenish the circulation.

Having done this blocking off, we can diffuse into the room a comparatively small volume of fresh air at very little temperature-difference from that already in the room, and can achieve happiness.

MINNESOTA STATE CAPITOL BUILDING AT ST. PAUL

Is there anything we meet much more uncomfortable on a warm, sunny day than the average attic space, especially that between an outer and an inner skylight?

Likewise, in cold weather this space gets very cold, and both conditions are transmitted to the room below. It is far easier to insulate, heat, cool and to control this intermediate space, where drafts do not matter particularly, than to ignore this space and to labor with the extremely delicate personal sensibilities in the room below.

Windows and walls can be made heat-and-leakage-resistant at much less cost than is involved by fortifying them with radiators and by furnishing a heating medium to these radiators. This will also lessen cleaning bill for walls and decorations, on account of the dust spots behind and above radiators.

Too much attention can not be paid to the type of diffusion of the air at the inlets and the outlets. If we dump a lot of air into a lofty heated room, at the top, and if the air so dumped is only a trifle cooler than the general air in the room, that cooler, heavier air will fall down on the heads of the audience at a

startlingly high velocity, increasing as the height is greater. It is necessary to use infinite tact, patience and discretion in delivering the cooler air into the room, often in many little jets, horizontally in the main, rather than vertically, giving the cool air a chance to mix with the warmer air and to absorb some of the heat from the original air.

If we ooze the cooler air in from below, we have even a more difficult problem, since the heavier, cooler air, like water, runs along the floor in shallow streams, seeking the lower levels, and causing draft-complaint.

When the entering air is much warmer than the room air, we find it rising to the top of the room, overheating the galleries and causing all manner of strange up-and-down currents and there is almost as much danger of complaint when we are delivering warm air as when we are delivering cool air.

When designing engineers and operating engineers acknowledge these conditions and provide for them in our legislative halls, we will get a higher percentage of happy legislators. Perhaps a few lives of our legislative patriots may be saved. I have faith that it would be worth while to try to save some of them.

SPECIFICATIONS

Does their preparation today impose a handicap?

By John D. Small

Sumerian Tablet, 3500 B.C. Photo by Courtesy of Field Museum of Natural History, Chicago

Early builders recorded specifications on clay tablets like the one shown

A GOOD many years ago a draftsman found it necessary to make notations on the border of a building plan. Among these notations he lettered the words "Everything omitted to be included."

Many changes have come about since that time in the writing of specifications. This art, as it might be termed, has gone through many stages of development and has been subjected to many influences. These changes are still going on to such an extent that a specification written a year ago might not be adequate for present conditions.

Forty years ago a specification was very short compared with the voluminous documents one often sees today when manufacturers and contractors have an important part in their construction. But there is less guessing now and more certainty of performance. Guessing is expensive. Often much more material was used than was actually necessary.

As the steel frame structure came into use, a properly written specification became more necessary. Specialists were employed for various phases of the engineering work. Specifications became longer and more detailed. But real improvement in writing specifications came very slowly. Errors made on one job were corrected in the next. Costly experiences necessitated more careful search for loopholes. The result was a tendency to overdo the matter. In an effort to cover everything sometimes so many words were used that the contractor often did not have time to read them through or understand them.

While early specifications were too short, many of the modern specifications are too long, with the result that such a mass of data contributes to confusion rather than to clearness.

Of course, all points should be covered in a specification, but duplication or unnecessary words should be avoided. If we were compelled to write our specifications on cylinders of clay as was done in building construction many centuries ago, we would be more careful in our use of words.

Care in Use of Terms

It appears, however, that specifications in general are likely to grow longer rather than shorter. New names and terms constantly are being added to the vocabulary of the engineer. New devices, new materials and new methods must be described.

There are many terms and expressions in connection with building construction which are easily misconstrued if unusual care is not taken. A specification may read, "The contractor is to furnish, etc." The writer of the specification intended that the contractor should furnish and install. But he neglected to make a specific statement to that effect. Another common expression is that certain equipment "Will be furnished," leaving out any specific statement as to who shall furnish it.

At one time it was common for engineers to specify one make of apparatus. There was not the variety of equipment available that there is today. But now

new types of equipment and new terms are constantly coming up.

As new types of equipment commenced to appear the words "or equal" came into use, and this led to differences of opinion as to whether the equipment installed was equal or not.

Another word which often has been the cause of controversy is "complete." "Complete" is capable of a variety of interpretations. When, for instance, is a boiler "complete"? The safest procedure is to say, "Complete with," and then explain definitely what is meant by complete. Such loopholes in specifications have caused a lot of ill feeling especially when work has been taken at a low figure. The phrase "To the satisfaction of the architect" is also often responsible for dissatisfaction. It should not appear in a specification, because it is not specific.

When the term "or equal approved" was introduced it seemed to take care of the problem for a time, but later specification writers made use of the term "or equal in the opinion of and approved by the architect," which also is objectionable.

In recent years, however, a new note has been injected into building construction and equipment. More care is taken in seeing that the buildings will pay a certain percentage on the investment. Elaborate and ambitious plans are made for the buildings. The owners or promoters want the finest of equipment and the best service for their tenants that money can buy. But the question arises, "What revenue may be expected from the investment?" The result is that modification and frequently extensive changes in the plans and specifications are made. As a matter of fact, specifications are practically ignored in some cases where it is imperative to keep the costs within certain limits.

Present Day Specifications

A specification is essentially a story of the work to be done, not merely a list of materials. What is to be done may constitute 25 per cent and how it is to done 75 per cent of the specification.

The approved present day specification must be general. That is, it must present a clear cut picture of the job as a whole. Also, in order to live up to its name, it must be specific. It must be concise, definite and so written as to be clearly understood. With all this it must be flexible enough to permit of a broad interpretation while keeping within the limits of first class construction and in order to keep down operating and maintenance cost. Needless to say, it is the ambition of all concerned to get the most they can for the money.

There must be a logical sequence of headings, and information relative to any heading must be found under that heading and not in another part of the specification. I recall looking through a specification for a clause referring to the smoke breeching. It was finally found under the heading of "foundations."

A heating specification, for instance, should start with the boiler. This should be followed in logical order by the piping, valves, steam specialties and auxiliaries, the traps, steam circulating devices, etc. Following this, the supports, pipe coverings and the painting should be described. The conclusion should relate to testing and acceptance.

Similarly, a ventilating specification should start with the air intake, followed by the tempering heaters, air washers, reheaters and air valves. This should be followed by consideration of the fans, motors, ducts, registers, temperature regulation, supports and finally the testing and acceptance. In other words, start at the source of supply or the prime movers and build the specification as you would build a house.

Extras

Extras are the cause of much dissatisfaction on the part of the owner, so precaution should be taken to avoid the necessity for extras. The owner is entitled to believe that the contract covers everything required for the completion of the job. Extras are probably the cause of more dissatisfaction than anything else in the writing of specifications. The writer of the specifications can do more to avoid dissatisfaction and to promote harmonious relations among all concerned than any other person who has anything to do with the job. Properly prepared specifications, together with a sense of fair dealing by all parties concerned, will do much to prevent misunderstanding.

Can Specifications Be Standardized?

The question often has been asked whether specifications can be standardized. For the larger construction, at least, such a plan does not seem to be practical. No two buildings are exactly alike in design and equipment. The conditions vary with each job. Each building must be studied and specifications must be written taking into consideration special requirements and local conditions. The more care exercised in writing specifications the more likely will the job be completed without a hitch. If a certain type of apparatus is desired, the specification should not demand construction or methods of operation foreign to the particular type of apparatus selected, as this complicates the bidding.

It seems necessary in many cases to specify a certain type of equipment in order to get what is desired. Recently, however, owners are inclined to agree to more or less open specifications. The best way is to determine the class of service required, consider the amount of money to be spent and specify the class of material or type of apparatus best suited to render this service.

Certain standards may be cited and the intents clearly expressed, avoiding unnecessary words. Too detailed specification for an inexpensive apparatus is just as much a handicap as too general specification for a complex job. In other words, the specification must conform to the job, and for this reason it is not practical from the viewpoint of the designer to standardize specifications.

Certain organizations have endeavored to standardize specifications. The American Society of Heating and Ventilating Engineers have entertained the hope that data regarding standard specifications might be incorporated into the A. S. H. V. E Guide.

Progress in Dust Control

By H. C. Murphy

THE transmission of many respiratory infections can be clearly traced to dust particles as carriers. The ordinary bacterium is relatively as heavy as an apple and would fall from its own weight if it were not caught and carried along from place and place and person to person on the floating dust particle. This phase of infection is well understood and today practically every modern school, hotel, clubhouse and similar gathering place is equipped with an air cleaner of some sort.

The writer of these articles is chairman of the engineering committee of the Air Filter Association. For the last four or five years he has conducted a survey covering dust conditions in twenty-four American cities. This was later taken up by the committee on atmospheric smoke and dust of the American Society of Heating and Ventilating Engineers, of which Mr. Murphy is a member and a more extended survey in conjunction with the United States Weather Bureau in a number of these cities is now under way.

The Danger of Indoor Dust

Systems for dust protection are available ranging from those comparatively inexpensive devices for one room or all the rooms in a home to systems which are applied to the buildings of largest size. These systems will materially assist in the control of such disorders as hay fever, many cases of bronchial asthma, and similar allergic diseases. These disturbances are caused in most cases by irritating impurities in the air, usually pollens, such as ragweed, rose pollen, various forms of house dust and a wide range of usually unsuspected air impurities. Investigations along these lines are now under way by Dr. W. Storn Van Leeuwen of Leiden, Holland.

Hay Fever and Air Filtration

There are over 1,350,000 hay fever sufferers in America. It has been called "a rich man's disease," as the most widely practiced remedy has been the removal of the patient to a climate which is free—or at least relatively free—of the particular irritating air impurity which is causing the trouble. This has resulted in the development of various hay fever resorts in different parts of the country. Experimentation has shown that some of these resorts are beneficial to certain types of hay fever and practically valueless to others. It has been found entirely practical, both in this country and abroad, to alleviate practically all respiratory infections of this type by the installation in the patient's room or living quarters of a forced air supply equipped with an efficient air cleaner.

Air Filtration for Industrial Plants

The havoc caused by dust in industrial plants is today well understood. The continued breathing of certain kinds of dust induces a condition of chronic asthma or bronchitis. The continued irritation of the sensitive walls of the bronchial tubes and the lungs makes them especially susceptible to infection by the tubercle bacillus. Steel workers, polishers, foundry men, textile workers and felt hat makers suffer considerably from these conditions. Certain poisonous dusts such as the lead compounds used in the manufacture of storage batteries, noxious fumes generated in the manufacture of vitreous enamel, the poisonous dusts created in the manufacture of explosives are well appreciated and in certain communities regulations have been established to protect the health of such workers.

The danger from dust explosions in factories is more serious than is generally appreciated by the public at large. Two primary conditions are necessary for a destructive explosive—that is, the presence of a dust cloud and the possibility of ignition. Either of these conditions separately may cause no trouble, but if they both occur at the same time explosion is the result.

Past and Present Statuses of Air Filtration

The progressive steps in the art of air cleaning have been largely, first, mechanical screening or removal of solids with cloth or metal screens. This served, and in fact still serves, for certain purposes, but it was found to be an inadequate solution of the problem. It stopped the large dirt, but the smaller particles went through—for instance, ordinary commercial cement is guaranteed by the manufacturer to have passed through a 100-mesh screen. It is apparent that the 40-mesh screen, which was ordinarily used in general ventilation work, allows a large part of the dirt to pass through. On the other hand, by its very nature, a screen fine enough to remove small dirt particles soon presented excessive obstruction to the air flow.

There recently have been made available dry filters of this type with renewable media, usually in the form of wood fibre or paper mats, which can be mechanically agitated for cleaning and replaced by a new sheet when the media has been worn.

One of the decided advancements in the art of air conditioning which largely eliminated cheese cloth and screens from general ventilation work was the so-called air washer, usually a combination of a spray chamber and wet scrubbing surface arranged

to be flushed constantly with water. Various types of considerable ingenuity were designed and their use greatly extended the field of air cleaning equipment. Shortly after the application of air washers reached its peak, the characteristics of the dust problem in our city life changed. With the advent of a new method of locomotion, the automobile, and intensive manufacturing activities, city dust which had been largely soluble in water was replaced by soot and unconsumed carbons—light greasy substances insoluble in and almost totally unaffected by water. These conditions presented complications, as the methods used were found to be inefficient in the removal of soot and carbons, and renewed investigation was given to the so-called air filter.

In reality, most modern air filters do not "filter" the air at all. Cheese cloth or dry filters are as a rule true filters. Most of the types now in use, however, operate on the principle of adhesive impingement. This principle is by no means new. It is a direct infringement of an old and much used air filter—the human nostril. The efficiency of the nostril in dust removal is surprising and the media of the most widely used air cleaning devices today simulates very closely the moist, porous surface and mucus coated hairs of the human nostril.

Recently there have become available so-called automatic air filters, ingenious devices which automatically clean the air and then clean themselves. Even this, however, is not new—nature has provided in the human bronchial tubes a most amazingly efficient "automatic air filter." The walls of the bronchial tubes are lined with a layer of epithelical cells that are arranged with great numbers of microscopic hairs or "cilia." These "cilia" constantly wave to and fro in such a way that any particles which might have passed through the "air filter" in the nostril are caught and carried upward and discharged outward.

Outdoor Dust

RECENT investigations in this country and abroad have shown a surprisingly close relationship between excessive pollution of city air by smokes and the abnormal prevalence of respiratory infections.

In England, preliminary investigations have been made by the government meteorological office as to the relation of dirty air and health, and an attempt has been made to correlate the amount of suspended impurities in the air with the number of deaths in London. In Germany, the investigations, headed by Dr. Louis Ascher, were apparently conclusive of the connection between air pollution and abnormally high death rates from pneumonia, tuberculosis, etc.

In co-operation with the U. S. Weather Bureau the research committee of the American Society of Heating and Ventilating Engineers is conducting investigations in thirteen American cities to discover, if possible, the connection between excessive city dust conditions and abnormal prevalence of respiratory infections.

Daily dust measurements by the U. S. Weather Bureau are tabulated with reports from the local boards of health showing the incident of air-borne infections and an attempt will be made to co-operate with all civic organizations interested in smoke and dust preventions.

The cities in which the investigations are now under way are:

Atlanta	New York
Boston	Madison, Wis.
Chicago	Pittsburgh
Cincinnati	St. Louis
Denver	Salt Lake City
Detroit	Washington, D. C.
Lincoln, Neb.	

Whether the abnormal prevalence of certain diseases in cities with excessive air pollution is due to the pathogenic organisms carried on air dust or to the decrease in sunlight caused by smoke is at present a debatable question. While considerable research is necessary on this subject, it seems quite evident that the continued pollution of our city air tends to shorten the life span of its inhabitants.

The United States Public Health Service reports that in lower Manhattan on sunny days during January 1927, there was an average loss of sunlight intensity, because of smoke and air contamination, of 42 per cent at 8 A. M. It is probable that these figures are less than the average for our larger cities.

It is possibly significant that the cities having the most severe smoke conditions also show the greatest loss in sunshine. Taking the sunshine reports as measured by the United States Weather Bureau for the three winter months—December, January and February, of 1926, as compared with the corresponding three months in 1916—ten years earlier—the average loss of sunshine is as follows:

	Average Decrease in Sunshine
1. Cincinnati	17%
2. St. Louis	13%
3. Chicago	12%
4. Cleveland	10%
5. Pittsburgh	8%
6. Detroit	7%
7. Indianapolis	6%
8. Toledo	6%
9. Atlanta	6%
10. Des Moines	6%

Taking the average dust conditions for the same cities measured over a period of four years as reported to the American Society of Heating & Ventilating Engineers by the writer, the average number of dust particles per cubic feet is as follows:

	Average Number of Dust Particles Per Cubic Feet
1. St. Louis	17,600
2. Cincinnati	16,700
3. Pittsburgh	16,100
4. Detroit	15,300
5. Chicago	14,300
6. Indianapolis	14,060
7. Cleveland	13,840
8. Toledo	10,700
9. Atlanta	9,460
10. Des Moines	8,370

By close supervision of our water supply and sewage disposal we have practically eliminated water borne diseases such as typhoid fever, cholera, etc.; by government supervision of our food supply we are guaranteed pure foods; but the bacterial content and impurities of the air we breathe are practically disregarded. Sanitation of the air stands about where it did one hundred years ago.

Refrigeration —

Its Development and Its Future

By Lewis Lipman

[Editor's foreword:—In the May issue of "Heating, Piping and Air Conditioning," Mr. Lipman traced the development of refrigeration to its present status and said that the field of refrigeration can now be naturally divided into three general groups:

(1) *Large commercial*
(2) *Small commercial*
(3) *Household units, etc.*

The large commercial field, he pointed out, covers all plants of nominal twenty tons capacity per day and over, necessitating the continuous services of licensed operating engineers. This group started, as stated in the first part of this article, with the ice-making plants. Following this came the cold storage plant, or warehouse; then the dairies and ice cream factories, including the assembly plants where the milk is brought together for shipment to the dairies and where the animal and other sensible heat was removed to a degree.

Mr. Lipman's article continues below. Further articles from him and other writers on refrigeration will be scheduled for future issues.]

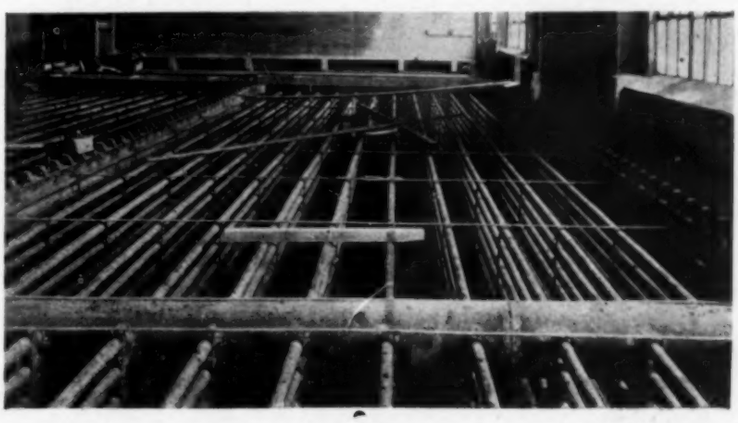
THE breweries were by this time, making great strides in developing their refrigeration applications. Following this, the steel plants found uses for considerable tonnage. Hotels were now beginning to develop their own refrigeration and were improving their service greatly thereby. Then followed the more specialized applications to various manufacturing processes, such as the making or producing of soap, explosives, baking powder, sugar, baked goods, chemicals, paint and varnish, paper, rubber, tobacco, glass, printing, salt, leather, and canned and preserved fruits as well as the storage of furs, flowers and other commodities. Our space precludes even lightly touching upon the many other applications in so limited an article. Many of these applications will be discussed in future articles.

A Five-Year-Old Industry

The small commercial group embraces that field using equipment of from twenty tons to one-quarter-ton capacity, not needing an engineer to operate it because of automatic controls. These consist of temperature, pressure and operating controls, capable of handling every phase of the equipment. These have been commercially practical for only about four or five years, although efforts were inaugurated along this line some twelve years ago. This field consists of installations in dairy farms, packer's distributing stations, small ice cream plants, butcher shops, bakeries, drinking-water equipment, restaurants, delicatessens, large groceries, fur storages, poultry storage houses, and others.

The household unit serves homes, apartments, yachts, dining cars, small butcher and grocery shops, ice-cream cabinets and soda fountains. These installations are entirely automatic in operation.

Piping in Plant Which Supplies Ice for Refrigerating Cars



Refrigeration Problems

In this article, we can give but few of the general items of interest to the average reader in the determination of his refrigerating problems. It may be needless to say that all problems must resolve themselves into size of investment and returns thereon. These returns may be either direct or indirect; that is, a positive financial return may be shown (direct return); or a product or conditions may be improved (indirect return). In some instances, a refrigerating installation may show both direct and indirect returns. This, of course, is the ideal condition.

Costs—Depreciation—Operating Expenses—Returns

In order to find what the returns are likely to be, it is, of course, necessary to know the cost of installation, depreciation and operating expenses. In considering these items, we must, of course, follow the old geometrical procedure of "given" and "to prove." We are given the conditions, the limitations, the possibilities, and their application to the former points. From these we prove or disprove our case.

Given, for argument's sake, a con-

dition of unsatisfactory and insanitary drinking water in an Oklahoma oil refinery; it may be that the present unsatisfactory way is with "water-boys," who roam all over the refinery and tank fields, distributing water from a bucket with a dipper to the men. The territory under consideration may consist of many acres and the time required to circulate "ice water" by this method, may be entirely inadequate.

As to limitations, it may be that the financial conditions and the future outlook would warrant an investment of only a certain amount; or it may be contemplated to indulge in some very comprehensive alterations of the plant layout within three or five years.

Perhaps the management is considering a low power rate or a different grouping of labor at points within the plant area, permitting a quite definite centralization of the drinking fountains, instead of wide distribution. As to cooling of drinking water then, it is essential first to determine whether a single, comparatively large unit, located, let us say, at *1*, the power house, and circulating from that point either refrigerated brine to chill the drinking water at certain points, or, *2*, a circulation of the drinking water, directly chilled from the power-house, or, perhaps, *3*, a number of smaller refrigerating units, placed at points of vantage and automatically controlled, would be the best way to handle the matter.

There enter into this problem not only the first cost of installation but also the question of maintenance and depreciation. There would be involved a large refrigeration loss through the circulation of the brine or ice-water around the grounds, as well as a considerable pumping cost. The lines must be figured large enough so that the changing volume of water drawn may not appreciably affect the pressures at the fountains and also, so that the skin-friction due to circulation should not build up the power cost to a point that is too high. On the other hand, the circulation must be rapid enough to return the unused water to the central chilling unit without undue temperature rise.

Air Receivers and Compressed Air Piping

By H. L. Kauffman

COMPRESSED air is now so widely used in industrial plants, in garages, etc., that the design and layout of air receivers and compressed air piping represent a discussion of widespread interest.

In the first place, it should be borne in mind that the discharge from an air compressor is more or less pulsating in character. An air receiver, therefore, is a sort of a "rectifier." It receives and absorbs these pulsations and delivers a steady flow, upon demand, to the line. In other words, an air receiver is, in a very small degree, an accumulator in which excess energy is stored for a while and then later withdrawn. However, an air receiver cannot be relied upon, in any large degree, as an effective means of power storage.

"How large should an air receiver be?" is a question that frequently confronts designing engineers.

The answer to that question is that an air receiver cannot be too large, nor can there be too many receivers, provided that leakage is carefully avoided in the connections when the receiver is installed.

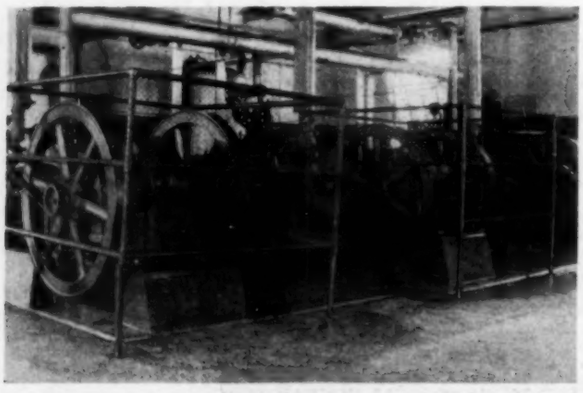


FIG. 1.—A COMPRESSOR ROOM IN OIL REFINERY SHOWING AIR RECEIVERS IN THE BACKGROUND

Ample air-receiver capacity is especially advisable in plants where the demand for air is of such an intermittent character. Having the receiver large enough makes the problem of regulation easier, and assists the governor or regulator of the compressor in maintaining a steady pressure.

Location and Piping of Receiver

The air receiver should be placed as closely as possible to the compressor or after-cooler, and pipe of sufficient size should be used for connecting it up. It also should be mentioned that it is better to make the pipe between the compressor and the receiver a size larger than that leaving the receiver. In the former section of piping, elbows should be avoided if possible, and wide-sweep bends given preference.

In planning the layout for an air compressor and receiver, remember, above everything else, that a valve should never be used between compressor and receiver unless the former is protected by a safety valve on the side nearest the compressor. To do otherwise is dangerous.

Each receiver should be fitted with a safety or relief valve; and where the receiver is out-of-doors this relief valve should be piped back into the compressor room to avoid freezing.

Where the receiver is exposed to the weather, it should be painted to protect it against rusting or corrosion. Particular attention should be given to the joints and openings and manhole. Rusting at these edges will soon weaken the receiver and cause leaks. Occasional scraping away of the rust and repainting will prevent this.

There is some cooling of the air in the receiver; and since cooling means condensation of water vapor, the

receiver should preferably be placed out-of-doors, where its cooling effect will produce dryer air. A smaller secondary receiver or receivers placed along the line at some distance will still further cool and dry the air. Every receiver should have a drain-cock, at its lowest point, which should be opened regularly and often for the discharge of accumulated water.

Primary or main receivers, or those next to the compressor, should be so piped up that the air will enter at the top and leave near, but a little above, the bottom. On secondary receivers this arrangement should be reversed. On long pipe-line systems small receivers, or moisture traps, should be placed at the low points in the lines, the piping entering and leaving at the top. These will catch the moisture condensed in the lines, which moisture should be withdrawn frequently through a drain-cock.

As a guide in seeing that an air receiver of ample capacity is obtained, Table 1 is given.

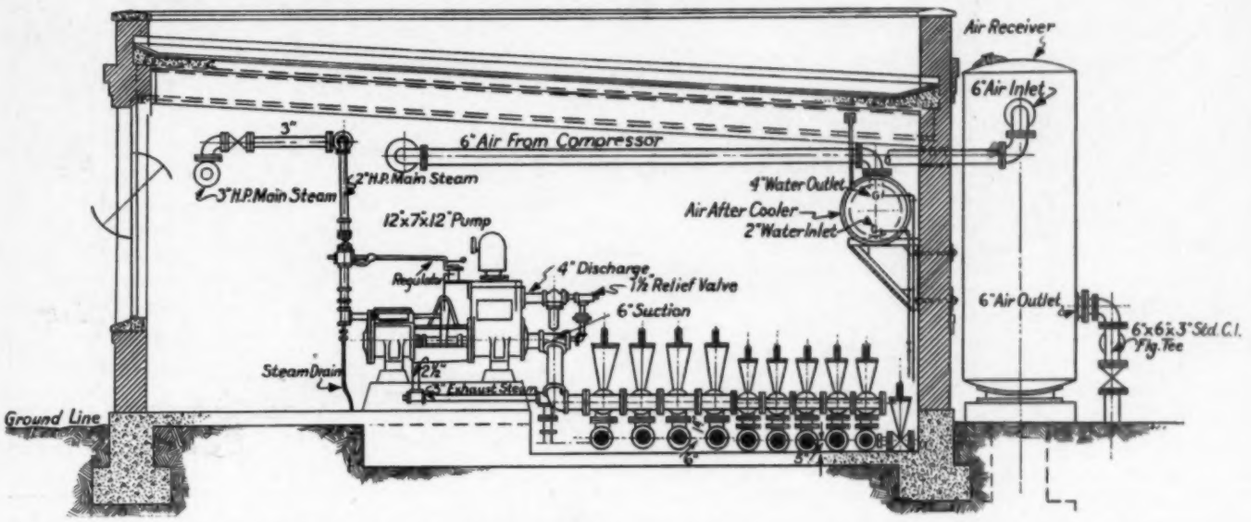


FIG. 2.—SHOWING LAYOUT AND PIPING OF AN AIR RECEIVER IN OIL TREATING PLANT APPEARING IN FIG. 1

Air Compressor Piping

Piping for an automatic assembled unit should be at least ⅜-in. in diameter; likewise, of good quality and with all joints absolutely air-tight. Joints should be sealed with either litharge or white lead, and should be tested under pressure for leaks with soap solution or by feeding to the intake of the compressor used for test a volatile odorous oil, such as oil of peppermint.

To eliminate the inconvenience of frozen air lines, all outside piping should be laid underground below the freezing zone, and with a minimum of bends and pockets. If at all possible, piping should slope to a drainage point where drain cocks should be placed. Where low temperatures are common, it is often worth the additional expense to lay any air pipe exposed to the cold within another pipe of larger diameter. Such an arrangement provides an insulation of air that minimizes the possibility of freezing; and, further, in case of broken or leaky lines, makes it possible to remove the pipe for repair without tearing up concrete, if the line is installed under concrete.

Any condition causing loss of air will operate an automatic compressor until the condition is discovered and remedied. Air leaks are very expensive and should be corrected immediately. If a compressor appears to be pumping too slow or to be pumping too often, a leak is probably the cause.

The need for prompt attention to even a small leak becomes apparent when the cost is considered. An opening as small as 1/64-in. in diameter will consume over 20,000 cubic feet of air per month at an average pressure of 125 pounds. This represents many hours of useless wear and tear on the compressor. In addition, one such leak will cost $3.70 per month for electricity, based on a rate of 10 cents per kilowatt hour.

TABLE I—DATA ON AIR RECEIVERS

Diameter in Inches	Length in Feet	Contents Cubic Feet (Approx.)	Diameter of Safety Valve in Inches	Diameter of Inlet and Discharge Openings in Inches	Compressor Capacity in Cubic Feet of Free Air per Minute for which Receiver is best adapted
For 110 Pounds Working Pressure. Tested to 165 Pounds Water Pressure.					
18	6	10	1	2½	90
24	6	18	1½	2½	120
30	6	29	1½	3	150
36	6	42	1½	4	150 to 200
36	8	56	1½	4	200 to 300
42	8	77	2	5	300 to 500
42	10	96	2	6	500 to 700
48	8	100	2½	6	500 to 800
48	12	150	2½	8	700 to 1200
54	12	190	2½	8	1230 to 2100
60	14	275	2½	10	2000 to 3000
66	18	415	2½	10	3000 and over
24	6	18	1½	4	(These are only
36	6	42	1½	6	furnished horizon-
48	8	100	2½	6	tal style and are used as water traps in lines.)
For 150 Pounds Working Pressure. Tested to 225 Pounds Water Pressure.					
18	6	10	1	2½	135
24	6	18	1½	2½	180
30	6	29	1½	3	225
36	6	42	1½	4	225 to 300
36	8	56	1½	4	300 to 450
42	8	77	2	5	450 to 750
42	10	96	2	6	750 to 1050
48	12	150	2½	8	1050 to 1800
54	12	190	2½	8	1800 to 3000
60	14	275	2½	10	3000 to 4500

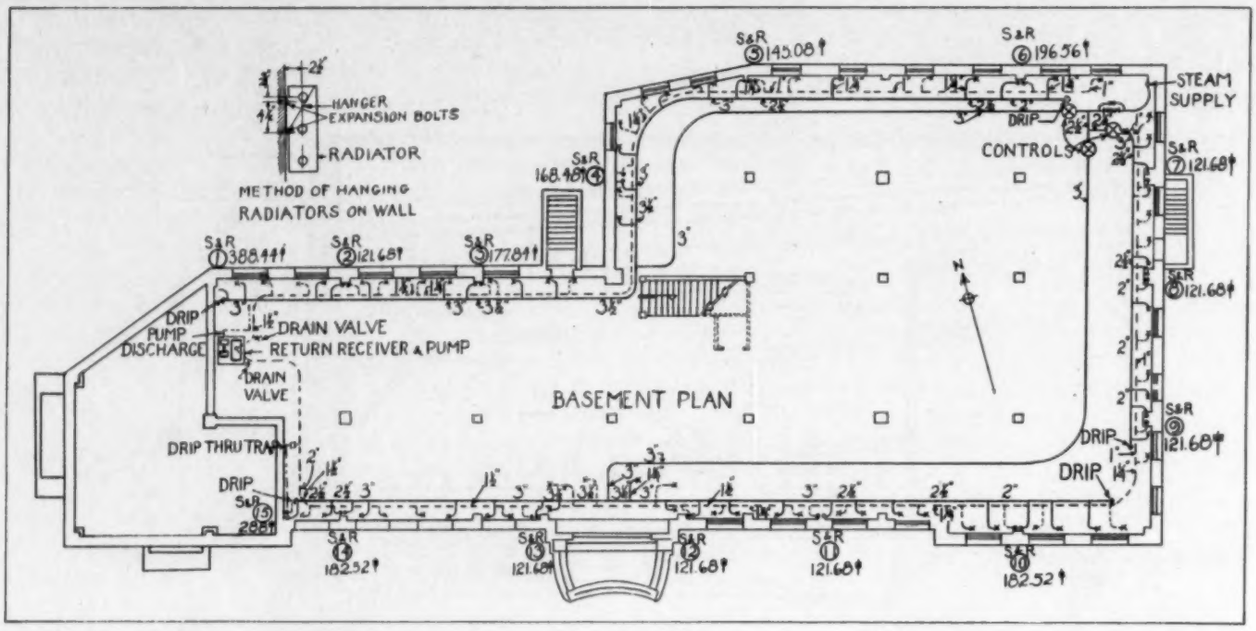


FIG. 1.—BASEMENT PLAN FOR THE HEATING SYSTEM OF THE NEW OFFICE BUILDING OF THE CARBIDE AND CARBON CHEMICALS CORPORATION

Note:—1. All steam and return run-outs from mains to first floor radiators are 1-inch, unless shown otherwise. 2. Where horizontal run-outs to radiators are shown larger than 1-inch, the 1-inch vertical run is welded just before the bend in the vertical pipe begins. 3. X shows location of control valve.

Stream Line Piping

The modern trend in heating system design is well exemplified in the new office building of the Carbide & Carbon Chemicals Corporation

By Webster Tallmadge

FOR twenty years the design of steam piping sizes for direct radiation heating systems was largely based upon the Donnelly rule-of-thumb of one ounce pressure drop, due to the frictional resistance of the pipe, for each one hundred feet of run. Little attention was paid to uniform distribution of steam, the economy in fuel or regulation of temperature other than in exceptional cases.

During the last ten years the increased costs of fuel, labor and equipment, together with the tremendous increase in the number of large buildings, especially the tall office building with a multiplicity of relatively small radiators on high risers, have made it necessary to study more precisely the steam distribution and pipe friction.

The turbulence in the flow at the sharp turns of elbows and tees has long been recognized as materially affecting the resistance. Thus, among the pipe fitting contractors welding has become very popular, due to the convenience and economy of sending portable welding outfits directly to the work to be done. In many cases, risers and mains above certain sizes have been welded length upon length but little has been done in the way of completely

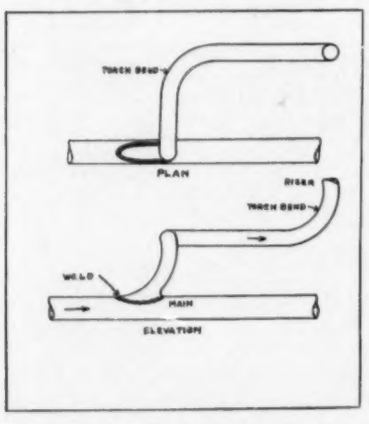


FIG. 2.—AN EXAMPLE OF STREAM LINE WELDING

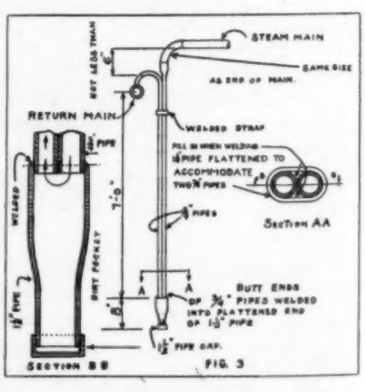


FIG. 3.—METHOD OF DRIPPING END OF STEAM MAIN THROUGH WELDED LOOP STEEL

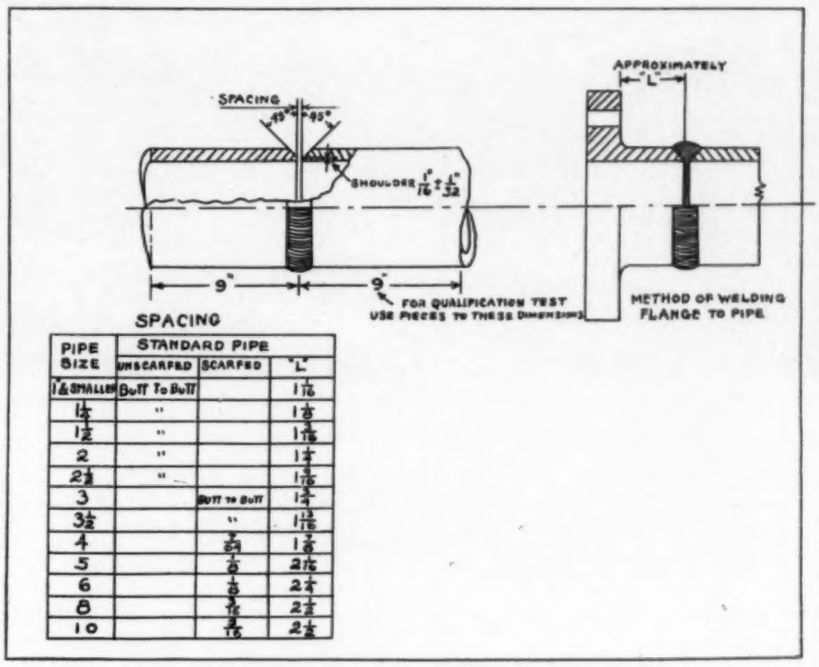
welded jobs and torch bending. It was decided for this building of the Carbide & Carbon Chemicals Corporation to make the heating "stream line" piping system, true to the term, zone it for exposure, use simplified orifice distribution and convector type heaters without traps or vacuum.

The quantity of convector heater capacity was computed and its location arranged in the usual manner. The importance of the exposures was studied and three zones decided upon. A preliminary riser diagram was first worked up with pipe loading but without sizes. From the flow shown by this preliminary riser diagram the pipe sizes were proportioned for pressure drop so that the orifice of the last heater would pass within four per cent of the flow through the orifice to the first heater in each zone. This resulted in obtaining a design to give uniform warming of all of the convector heaters.

A few of the characteristics of the piping layout and some of the welding details are shown in the illustrations.

Many of the bends necessary in the small pipe sizes and all of the offsets, even in the larger pipes, were made by local heating of the pipe with the torch at the place it was being fitted to the job. Standard forms of end of main drips and loop seals were devised as shown in the details.

This heating system is divided into three zones, a division which, because of the shape and location of the building, gives adequate flexibility for altering the heat supply due to change in the demand of the different exposures.



SPACING

PIPE SIZE	STANDARD PIPE		
	UNSCARFED	SCARFED	"L"
1 & SMALLER	Butt To Butt		1 1/16
1 1/4	"		1 1/16
1 1/2	"		1 1/16
2	"		1 1/4
2 1/2	"		1 5/16
3		Butt to Butt	1 3/4
3 1/2		"	1 13/16
4		1/2	1 7/8
5		5/8	2 1/16
6		3/4	2 1/4
8		7/8	2 1/2
10		1 1/16	2 1/2

FIG. 4.—SHOWING METHOD OF SPACING AND SCARFING OF PIPE FOR GAS WELDING

Due to the fact that for the major portion of the time the convector heaters will be only partially filled with steam, the condensate is cooled by the remaining convector surface. Return temperatures average less than 100 deg. fahr. The returned condensate flows to an open vented receiver from which it is pumped to the boiler house for reuse of the pure water. The residual air in the system at starting time is displaced by the steam flowing through the return piping to the vent in the return receiver.

The welding was carried on under definite welding specifications developed from standard procedure control for this class of welded construction to insure sound joints and to preclude protended weld metal within the pipes. Mild steel standard weight pipe was used throughout the system.

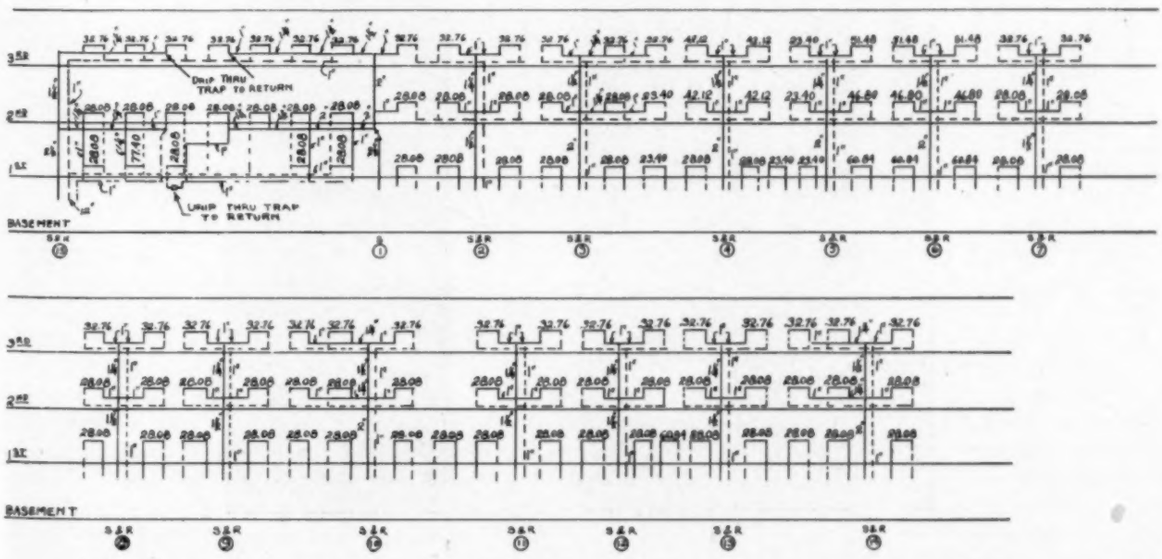



FIG. 5.—HEATING RISER DIAGRAM FOR CARBIDE AND CARBON CHEMICALS CORPORATION BUILDING

Climate and its Relationship to Body Function

Fig. 1.—Cincinnati General Hospital, Where Studies Are Being Made On the Control of Air Environment

STUDIES now proceeding at the Cincinnati General Hospital under the direction of Dr. C. A. Mills have been planned to bring out the ways in which climatic extremes affect the body functions more or less severely, often fatally, to devise proper corrective measures and especially to determine the cooling necessary to overcome the deleterious effects of moist heat.

It was during his service with the Peking Union Medical College in China (supported by the Rockefeller Foundation) that Dr. Mills first observed the severe disturbances of bodily function resulting from the prolonged period of humid heat of the Oriental summer, where the temperature and relative humidity both remain very high almost continuously, day and night over a period of six or eight weeks and closely approximate the limit of human endurance.

Under such conditions the heat production in the body is suppressed to a minimum on account of the difficulty of heat loss, and this affects particularly the adrenal glands, lowering their function. If the adrenal glands remain suppressed for several weeks they often become unable to respond to later demands for increased activity when cooler weather comes on, and certain distressing, it may be severe, symptoms ensue. These glands, after a fashion constitute the power station of the body, and in a people subjected yearly to several weeks of continuous depression by moist, hot weather, the result is bound to be a lowering of vigor and initiative. Just how much the summer climate of the Orient is responsible for the physical characteristics of the people remains to be seen from further studies.

United States dwellers in New England climate that runs the whole gamut of sunshine and shade, heat, cold, aridity, humidity, and ionization properties during the course of a single year, have energy to burn. They therefore develop into active, altruistic, many-sided individuals with vision and full capacity for long range objectives.

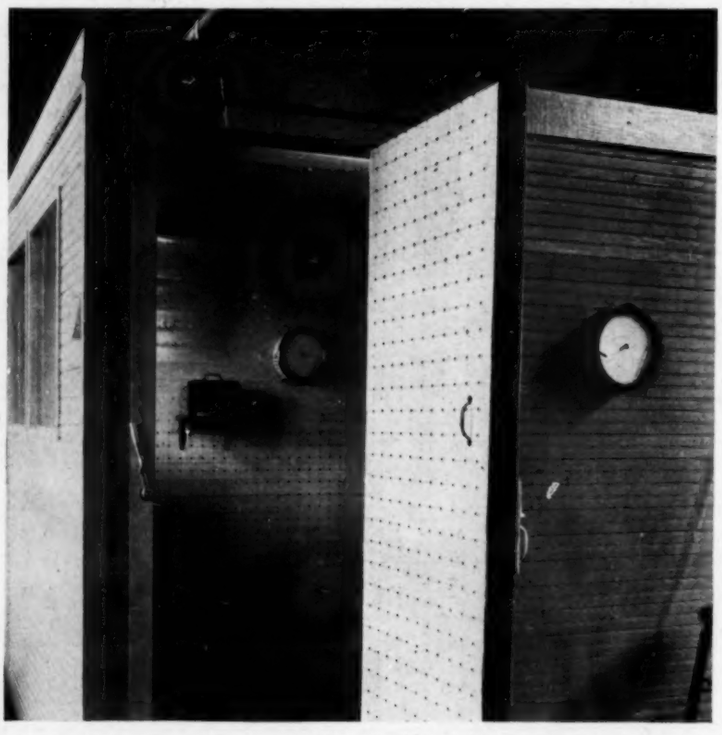


Fig. 2.—Exterior View of "Summer" Rooms, Where Effects of Hot, Moist Air Are Observed.

The Chinese people, drained of all surplus energy by the mere fact of tropical summer acclimatization, live mainly for self. Beyond immediate physical necessity, most of them can only with difficulty be sufficiently interested in their problems to better their hygienic condition. It is largely the outside world that is promoting sanitary science in China.

Conversely, the Chinese immigrant to America becomes

energetic, altruistic, shrewd. The overstimulated American, the world's chronic sufferer from hypertension, loses his pep in China. High blood pressure simply does not exist in him after he has weathered two or three tropical summers, unless it happens that he had previously developed arterio-sclerosis.

When Dr. Mills returned to America, his chief desire was to observe the physiological response to changing air environment. He observed tissue cell response to ozone-enriched air. He then worked with animals in sealed chambers to discover how far down the oxygen of normal air is used before an animal is prostrated from oxygen want.

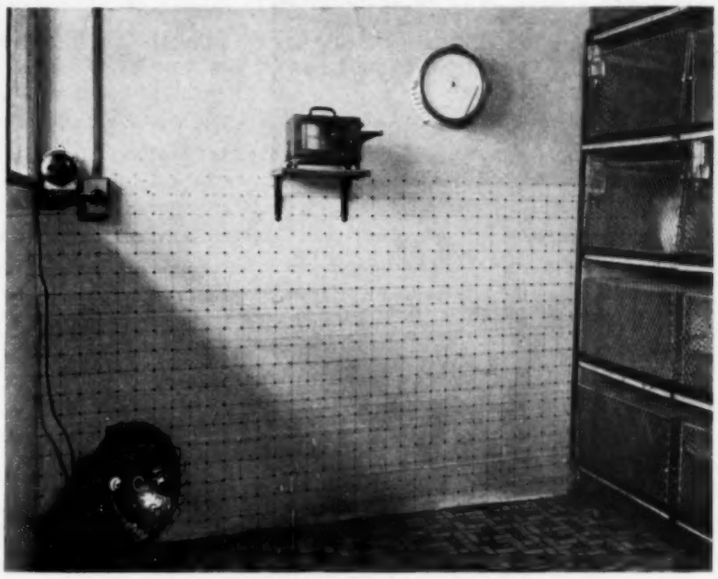


FIG. 3.—INTERIOR VIEW OF "SUMMER" ROOM, SHOWING: ELECTRIC HEATING UNIT WITH AUTOMATIC MERCURY CONTROL, HYDROGRAPH, RECORDING THERMOMETER, ANIMAL RACK AND CAGES.

Air Conditioning for Treatment of Diseases

He found that oxygen is breathed from the usual 20 per cent in normal outside air down to 12 per cent before the animal is overcome. When arrangements were made to absorb the accumulations of carbon dioxide in the expired air, the oxygen content could be utilized down to 5 per cent. Irradiation of the air at this point had some slight effect, and permitted oxygen to be utilized down to 4 per cent.

He then imitated China's tropical summer to see how it would affect the experimental animal, and he found that the animal loses power to adapt itself and cannot cope with continuous hot and humid conditions. Without interruption or fluctuation from February on through the last six weeks of summer in July and August, China's summer heat ascends till the temperature day and night is 90 deg. fahr. or more, with humidity range between 80 and 90 per cent.

"This closely approaches the limits of physiological adaptation," states Dr. Mills. "The body's energy wanes. Resilience is gone. Severe disturbances of body functions occur. Experimental animals in the summer rooms easily succumb to minor causes.

"This suggests many measures for the treatment of disease, among them, air control to keep the humidity down when atmospheric heat is high; cold rooms for fever patients; hot, moist chambers for use when blood pressures get too high. Indeed, it does seem sure that climatic change of any type a physician may require for his patient can soon be prescribed and carried out within the hospital or in the patient's home. A climatic cure no longer needs to mean that a patient is banished from his home or sent away from the care of his own physician."

It is to such experiments as those under way in the Cincinnati General Hospital that we must look for the development of management technic in such matters and, more especially, for a definition of the operating factors that enter into air hygiene. Dr. Mills' observations are being conducted in two rooms. One registers perennial summer heat and high humidity. The other maintains winter conditions at all times. The work will proceed with animals until it definitely can be told what air environment is best for health. The later plans may well include the treatment of human beings by air environment alone, and preventive medicine may well write down the laws of health in terms of air control.

FIG. 4.—INTERIOR OF "WINTER" ROOM, SHOWING COOLING UNIT, RECORDING THERMOMETER, ANIMAL RACK AND CAGES.

Each experimental room is made of wood and cork, perfectly insulated against heat and cold. Coldproof doors are duly calked. The rooms are equipped alike

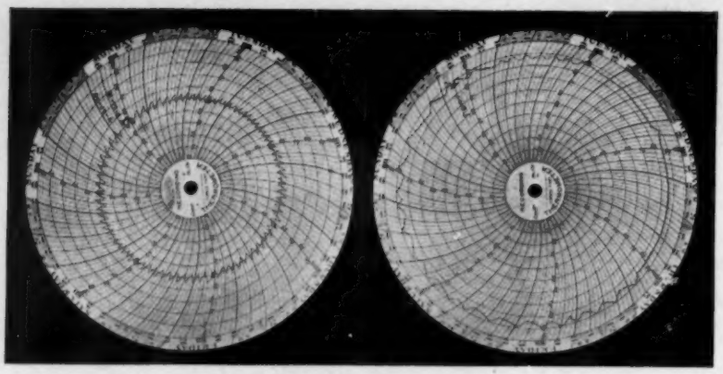


FIG. 5.—GRAPH SHOWING TEMPERATURE RANGE IN "WINTER" ROOM, AND "SUMMER" ROOM.

with ventilating apparatuses under absolute control. Air intake is measured, and exhaust fans give complete control. The warming is accomplished by means of electric heaters. The heat units are measured, too. A specially constructed electrical humidifier is installed, and thermostatic regulation is alike in both chambers. The fan for ventilation control is housed on top of the winter room. Compressor for refrigeration adjoins the winter room in the rear.

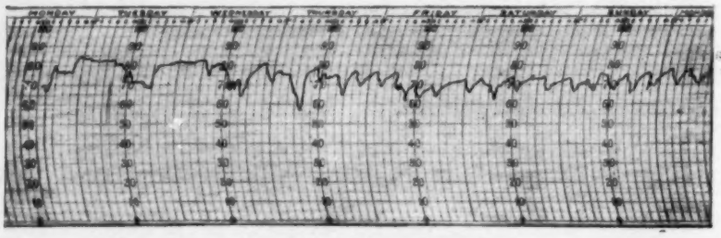


FIG. 6.—HUMIDTY GRAPH OF HOT ROOM.

The only difference between the rooms is that one chamber is equipped with a room cooling unit which draws air in from the bottom and delivers it at any temperature that may be desired at rate of 450 cubic feet per minute. This enables the maintenance in one room of a "winter" climate ranging between 40 and 50 deg. fahr., with a relative humidity close to 30 per cent. The "summer" climate represents a tropical climate with temperature between 85 and 90 deg. fahr., with humidity between 70 and 80 per cent.

Health and Environment

This temperature is about as high as experimental animals will stand. Rats and rabbits are used. Even a slight fluctuation higher than this will cause the death of some animals in a very short space of time.

"Health is a state of satisfactory adjustment of physiological function to the surrounding environment," states Dr. Mills. "The powers of adaptation fail with rising temperature accompanied by high moisture content, when the cooling power of the surrounding atmosphere is lost. Disturbance of body function, with lowered resistance to disease, here is closely related to intense and humid heat.

"Acclimatization is a factor. Sudden changes may make quicker energy demands than the body is able to meet. Prolonged exposure to tropical heat exhausts the sources of human energy."

The studies described do not permit too great generalization. They point rather definitely to the type of room atmospheres man can secure indoors. They also suggest corrective atmospheres for certain disorders known to be directly related to atmospheric influences. We now have oxygen-enriched air for emergency use and for postoperative care, and will be able to secure curative atmospheres for many things when medical science tells us what to do. The time is ripe for full medical and engineering collaboration.

FIG. 7.—ROOM COOLING UNIT BEING ADJUSTED BY L. S. KEILHOLTZ, CHIEF ENGINEER.

High Pressures in CO_2 Piping Bring Unusual Problems

AMMONIA, which probably is the most frequently used of all refrigerants, has been ruled out of theater cooling work by all engineers who have any real experience along this line. Various substitutes have been tried from time to time and one of the most popular of these alternatives has proved to be carbon dioxide, or CO_2 as it is chemically designated.

This liquid-gas, which assumes both forms in the refrigeration process according to the temperature and pressure, possesses, in some ways, very remarkable properties. It is absolutely harmless when taken into the human system, being the gas used in soda water fountains and for carbonating the so-called soft drinks. It has an unusually wide range of refrigerating temperatures, reaching a temperature of 110 deg. fahr. below zero, and does not corrode or destroy the metals used for piping or machinery.

Its physical properties also are notable. For instance, when being compressed for refrigeration, only about 1/6 to 1/12 the amount of the compression required for some of the other refrigerants is necessary. The gas itself does not decompose and possesses only a small affinity for oils, water and other impurities. The gas is non-explosive and non-inflammable, and its presence in the atmosphere, even in considerable quantity, is not injurious.

It is only natural to suppose that with a gas and liquid whose properties differ so radically from ammonia there should be considerable difference in the method and materials used in its piping. As the cycle of refrigerating with CO_2 follows along the same lines as that with ammonia, anyone familiar with ammonia installations will have no trouble in following out the gas and liquid travel in the carbon dioxide refrigerating plant.

In refrigerating with CO_2 the first step is to compress the gas in a carbon-dioxide compressor and then to pass the high temperature, compressed gas through a water-cooled, double-pipe condenser in which the gas is cooled and condensed, dropping down and collecting in the liquid receiver located under the condenser. This is shown in the typical system illustrated in Fig. 1.

From the liquid receiver, the liquid flows up to and through the expansion valves and into the expansion or cooling coils, where it vaporizes or turns back to a gas owing to the warmth absorbed in the cooling coils from the outside, and also on account of the relief in pressure which occurs when the expansion valve is passed. From the coils, the expanded and intensely cold gas is carried back to the compressor, where it is re-compressed ready to repeat the cycle.

Pressures in CO_2 Piping

Piping for CO_2 gas and liquid lines has certain requirements peculiarly its own, and, at the same time, safely can have certain items neglected. The pressure under which such lines may operate is usually within the range of 800 lb. per sq. in. to 1400 lb. per sq. in., but with the usual temperatures of cooling water the pressures should not exceed 1100 lb. on the discharge line and 600 lb. on the suction line. In fact, with 70 deg. condenser water, the pressures should run 900 lb. to 1100 lb., but where the temperature of the condenser water goes up to 83 deg. fahr., as occurs on some installations, then the CO_2 discharge pressure may reach 1400 lb.

To keep a line tight with such pressures involves careful workmanship and special material. On the other hand, lines may be run up or down grade without difficulty and no pitch or dripping is necessary.

Naturally, the return or suction line does not carry as high a pressure as the discharge or supply line. The pressure in the suction line usually is from 300 lb. to 500 lb. per sq. in., this depending again on the temperature of cool-

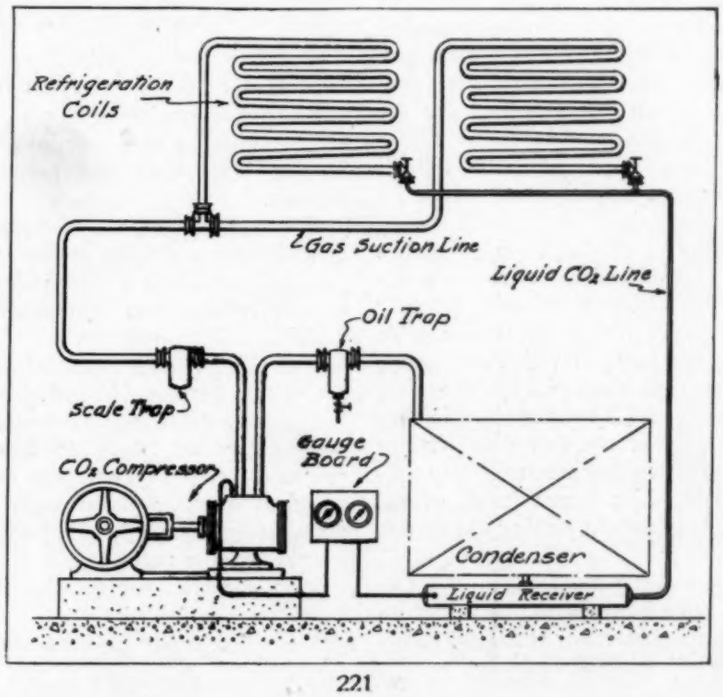


FIG. 1.—TYPICAL ARRANGEMENT OF A CARBONIC REFRIGERATION SYSTEM

ing water which is available for utilization.

No difference is made between the discharge and the suction line as far as pipe, fittings, valves or workmanship are concerned, as the reduced pressure is still so high as not to make it worth while to try to distinguish between the two lines so far as the item of pressure is concerned.

Carbonic lines are installed with special selected pipe of either steel or wrought iron, such pipe being tested to 1200 lb. hydrostatic pressure before being used in the work.

Galvanizing is not necessary on CO_2 piping, because the carbon dioxide has no effect on the metal. If water or damp conditions are apt to touch the outside of the pipe, outside galvanizing is desirable, but outside only —not inside.

Joints for CO_2 Piping

Where pipes are joined together, drop forged steel or air furnace iron flanges (see Fig. 2) are used with the pipe ends turned over the flanges and butted together. In these joints gaskets of corrugated copper or fiber are used. No elbows are employed wherever it is possible to avoid their use; in place of such fittings, pipe bends are substituted. In fact, the wise CO_2 installer eliminates all fittings, flanges, etc., just as far as possible.

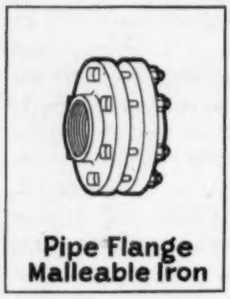


Fig. 2.—Malleable Iron Pipe Flanges Sometimes Used in CO_2 Piping

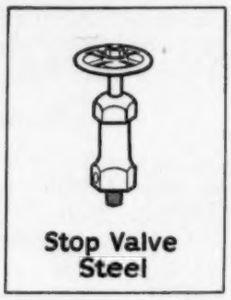


Fig. 3—Steel Stop Valve Used for Carbonic Systems

At branches from the line, it is necessary to use tees but these are made of drop forged steel or air furnace iron and are flanged. The joints between the tees and the pipe are made up the same as described for the flanged joints in the straight lines.

It is entirely permissible and even desirable to employ welding on such lines, as welding eliminates a lot of fittings and joints. Every joint removed from the line is an advantage where such high pressures are encountered. The only requisite of a welded carbonic-line joint is that it must be a first class weld, properly backed up with welding metal and more than capable of withstanding the test pressures to which the piping is subjected. Welding has been employed by some CO_2 installers almost exclusively, and by means of this they have been able to eliminate all fittings except stop valves and expansion valves. It is necessary when welding CO_2 pipes to see that the scale which forms inside of the pipe at the weld is blown out before putting the system into operation.

When it is necessary to install valves, valves of a special type are used, these being made particularly for this class of work. They have semi-steel or cast steel bodies with flanged ends and rising spindles, and are tested out to a pressure of 3000 lb. per sq. in. Fig. 3 shows a steel stop valve and Fig. 4 a drop forged steel stop valve of the type used for carbonic work.

Oil and Scale Traps Necessary

Between the compressor outlet and the condenser, an oil trap must be located with a valved drip, so that the oil can be blown out of the trap from time to time. It is not necessary to pipe this outlet to any particular point as the oil which comes first may be caught in a suitable receptacle and as soon as gas begins to flow the valve may be shut with the knowledge that all the oil has been expelled. Owing to the harmless nature of carbon dioxide gas, no bad effects result from this practice.

On the suction line going back to the compressor, and immediately before connecting to the machine, a scale trap is inserted to catch any scale or foreign matter which may be carried back from the system. The oil trap and scale trap combined will be sufficient to keep the system clean.

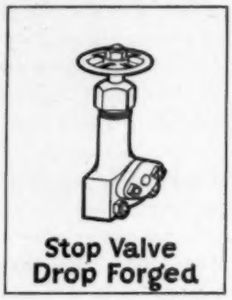


Fig. 4.—Drop Forged Type of Stop Valve for Carbon Dioxide Piping

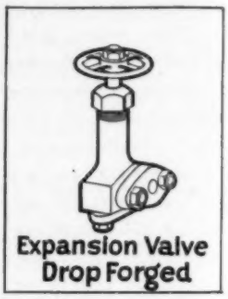


Fig. 5.—Drop Forged Expansion Valve Used on Cooling Coils of CO_2 Systems

Expansion valves (see Fig. 5) are located on each coil through which the liquid passes into the cooling coil, exactly the same as when ammonia is used. In front of each expansion valve is placed a strainer to catch any scale, flakes, grit or other impurities and foreign matter so that these will not lodge under the expansion valve or injure the seat.

Safety Appliances

Systems operating at the pressures used in carbonic refrigeration require certain safeguards against building up dangerously high pressures which might cause damage.

The first safeguard is to install pressure gauges which generally are run from special tappings on both the suction and discharge sides of the compressor to gauges conviently located on a gauge board where they are easily visible.

This does nothing to reduce undue pressures, but *does* notify the operator that such pressures exist.

The second safeguard is a pressure relief valve which is generally set 50 lb. to 100 lb. above the highest pressure likely to occur on the system. This relief valve, of course, will automatically prevent higher pressures being built up by allowing the gas or liquid to escape into the room.

With carbonic refrigeration this is not dangerous, as previously explained.

The third safety device is an electric pressure alarm

which rings a bell whenever excessive pressures are generated in the system. This, like the pressure gauge, does not automatically rectify such pressures, but notifies the operator so that the pressure can be reduced by him at once.

The fourth safeguard is a pressure cut-out which is so arranged as to cut off the current supply to the motor operating the compressor as soon as the pressures get too high.

The pressure gauges are always used and the automatic cut-out almost always. The relief valve and electric alarm bell are both valuable additions to the above and careful designers prefer to have all four if possible.

Covering

Covering is nearly always installed on the suction line for the sake of economy and also to prevent ice and frost building up on the pipes. For this purpose cork pipe covering of brine thickness is generally employed on the straight pipe and hair felt on the bends, specials, etc. On the liquid line, cork covering of ice water thickness is sometimes, but not always, used.

On a first class job, the covering may be recanvassed with an 8 oz. canvas jacket, sewed on. In fact, hair felt covering should be wrapped with canvas strips pitched on in order to keep it in shape. Pitching of the cork covering is optional. It is often omitted. A mineral rubber finish on the cork covering, where it runs through unfinished rooms, is also used in place of recanvassing in some instances.

Pipe Sizing

Pipe sizing for carbon dioxide lines does not often enter into the duties of the installer of such equipment, as the manufacturers of the equipment usually provide assembly drawings of the plant with all the lines shown and sizes marked. For making approximations in the early stages of design, and before the equipment is selected, the following method may be used which will give pipe diameters which should check very closely with the sizes which may finally be called for.

The properties of carbon dioxide as far as temperatures, pressures, cubic feet of gas per pound, and pounds per cubic foot of liquid are given in Table I for the temperatures between 20 deg. fahr. below zero and 86 deg. fahr. above zero.

In the ordinary theater installation where carbon dioxide is particularly suitable, the usual evaporating temperature is 35 deg. fahr., which prevents freezing the water, and the condensing temperature around 86 to 88 deg. fahr. in the hottest weather. The amount of carbon dioxide can then be roughly approximated by dividing the compressor capacity by the latent heat of the refrigerant at the evaporation temperature. It is known that one ton of refrigeration is practically 12,000 B.t.u. per hour, and if the liquid is vaporized at 35 deg. fahr., the pressure in the coil will be 526.4 lb. absolute (or 526.4 — 14.7 = 511.7 lb. gauge) as shown in Table I. The latent heat of the liquid at 35 deg. fahr. is about 98 B.t.u., which means that about 100 B.t.u. is absorbed by each pound of liquid in evaporating.

In a 100 ton plant the B.t.u. per hour would be

$$12{,}000 \times 100 = 1{,}200{,}000 \text{ B.t.u.}$$

and per minute would be

$$1{,}200{,}000 \div 60 = 20{,}000 \text{ B.t.u.}$$

while at 98 B.t.u. per lb. the number of pounds would be

$$20{,}000 \div 98 = 204 \text{ lb. per minute.}$$

As the liquid line is at 86 deg. fahr. (which, according to Table I, is 1039 lb. per sq. in. absolute pressure) the number of pounds per cubic foot is 37.41 and

$$204 \div 37.41 = 5.45 \text{ cu. ft.}$$

The velocity in the liquid line is usually taken around 500 feet per minute, so that this would give a pipe area in sq. ft of

$$5.45 \div 500 = .0109 \text{ sq. ft.}$$

or

$$144 \times .0109 = 1.58 \text{ sq. in. approx. or } 1\tfrac{1}{2}\text{-in. pipe.}$$

As the amount of refrigerant being circulated per minute is now roughly known and the size of the liquid line approximated, the size of the gas line from the cooling coil may also be calculated by the following method:

Amount of refrigerant per minute, 204 lb., which at 35 deg. fahr. has 0.16 cu. ft. per lb. or

$$204 \times 0.16 = 36.64 \text{ cu. ft.}$$

If a velocity in the gas line is taken as being between 1,000 and 1,500 feet per minute, the area of the pipe in sq. ft. will be

$$36.64 \div 1000 = 0.36 \text{ sq. ft.}$$

to

$$36.64 \div 1500 = 0.24 \text{ sq. ft.}$$

which is

$$0.36 \times 144 \text{ or } 5.184 \text{ sq. in.}$$

to

$$0.24 \times 144 \text{ or } 3.456 \text{ sq. in.}$$

This equals a 5-in. or 3½-in. pipe, according to the velocity contemplated. Usually the discharge pipe from the compressor to the condensor is one or two pipe sizes smaller than the suction line. In the above case this could be taken at 4-in. or 3-in., depending on whether a 5-in. or 3½-in. suction were used. In general, the high velocities are used only on the larger machines and the lower velocities are confined to the smaller units.

PROPERTIES OF CARBON DIOXIDE
Table I

Temperature Deg. Fahr.	Absolute Pressure Lb. per Sq. In.	Gas Cu. Ft. per Lb.	Liquid Lb. per Cu. Ft.	Latent Heat B.t.u. per Lb.
−20	220.6	0.42	64.34	126
−10	261.7	0.35	63.25	122
Zero	308.6	0.29	61.95	117
5	334.4	0.27	61.22	115.3
10	361.8	0.25	60.48	112.8
20	422.0	0.21	58.95	107.3
30	489.6	0.17	57.30	101.2
35	526.4	0.16	56.41	97.77
40	565.4	0.14	55.45	94.13
50	650.0	0.12	53.28	85.95
60	744.2	0.10	50.71	76.14
70	848.7	0.08	47.29	63.71
80	964.3	0.06	42.50	45.88
86	1039.0	0.05	37.41	27.00

The Basic Principles of Air Conditioning

By Edgar S. Miller*

AIR conditioning has been defined as the science of mechanically controlling the temperature, the humidity, the purity and the movement of the air within buildings and other enclosures. Actually the supreme purpose of complete air conditioning is the control of the *effects* of such air upon the persons and materials with which it comes in contact.

Ordinarily we do not consider mere heating as air conditioning, and rightly, if the foregoing definition is accepted; for mere heating is certain to fall far short of the control of even the temperature of the air actually affecting the bodies of persons or of certain materials exposed to the heated air. But broadly speaking, we think of the conditioning of anything as the process by which it is put into a certain condition or state. Speaking thus, any alteration of the condition or state of air for the specific purpose of modifying its effects might well be termed air conditioning of a sort.

The Constituents of Air

Air is generally considered a mechanical mixture of oxygen and nitrogen, about in the proportions of one to four. Certain inert gases, such as argon, neon and one or two others, exist in very small amounts; and because carbon dioxide, the product of the complete combustion of carbon, is also always present in a virtually constant percentage, it is rightfully regarded as a normal constituent of atmospheric air. An atmosphere wholly free from this compound of oxygen and carbon would inhibit the growth of plants and the formation of the important group of energy-producing foods called "carbohydrates," and animal life, as we know it, would be an impossibility.

Water vapor, though not strictly a constituent of air, is present in the atmosphere in varying amounts. It is usual to speak of this vapor as being "absorbed" by the air, and the analogy of the absorption of water by a sponge is a familiar one. However, water exists in air as a mixture of vapor with the gases mentioned, and is maintained as a vapor wholly by virtue of its own ability to absorb heat. As a matter of fact, the decrease in the density of air at high temperatures is not the reason for its ability to hold a larger quantity of water vapor, and the expanded sponge analogy is actually quite misleading. The vapor pressure of a cubic foot of space saturated with water vapor is entirely independent of any other pressure. Fill a box of one cubic foot capacity with air at a pressure of one or two or three atmospheres, or remove all air from it, so that the pressure of the atmosphere is nothing, and the vapor pressure of the water vapor within the enclosure will remain unaltered as long as the total heat is unchanged. This is to say that the quantity of water which can exist as a vapor is determined wholly by available heat and available water. Actually, when we speak of air as "absorbing moisture" and becoming "saturated," we mean the space occupied by the air and also by the water vapor "absorbed." But the terms, "the absorption of water by air," and the "saturation of air by water vapor" have become such common usage that it is usually more convenient to make use of them than to qualify each statement for the sake of scientific exactitude.

Laws of Air Conditioning

The salient facts concerning the phenomena of the evaporation of water and the consequent heat metamorphosis have become so generally accepted by scientists as to assume the dignity of laws. They were discovered and formulated by Willis H. Carrier, with whom it is my privilege to be associated as a coworker and a pupil. The "Carrier Laws" are as well known and as well established as those of Avogadro, Boyle, Charles or Newton, and they will be stated here only as a means of emphasizing points which I wish to make.

They are:

(A) When dry air is saturated adiabatically the temperature is reduced as the absolute humidity is increased, and the decrease of sensible heat is exactly equal to the simultaneous increase in latent heat due to evaporation.

(B) As the moisture content of air is increased adiabatically the temperature is reduced simultaneously until the vapor pressure corresponds to the temperature, when no further metamorphosis is possible. This ultimate temperature may be termed the temperature of adiabatic saturation.

(C) When an insulated body of water is permitted to evaporate freely into the air, it assumes the temperature of adiabatic saturation of that air and is unaffected by convection; i. e., the true wet-bulb temperature of air is identical with its temperature of adiabatic saturation.

From these three fundamentals a fourth principle may be deduced:

(D) The true wet-bulb temperature of air depends entirely upon the total of the sensible and the latent heat in the mixture of air and water vapor, and is independent of their relative proportions. In other words, the wet-bulb temperature of the air is constant providing the heat of the mixture of air and water vapor is constant.

It has been pretty generally established, even in the mind of the layman, that very warm air is capable of holding a large amount of water vapor, and that cold air can hold very little, yet it is to be doubted that all students of physics fully appreciate the significance of these facts. We think of the atmosphere as of chief importance to us because of its ability to support combustion. But this vast sea of air, at the bottom of which we live, has other functions of at least equal importance. Were it not for these other functions vegetable and animal life could not exist, and none of us would be particularly interested in any sort of combustion, because none of us would be alive.

There is a close relationship between the phenomenon of evaporation and the transformation of sensible to

* From a paper presented at meeting of A. S. M. E. in Kansas City, Mo., May, 1929.

latent heat, together with the reverse process, that is of the utmost significance. Whether we are cognizant of the facts or not, the effects of heat metamorphosis in the vaporization and condensation are far reaching.

Latent Heat

Almost everyone knows that liquid water boiling in the pressure of one atmosphere has a temperature of about 212 deg. fahr. Notwithstanding the fact that a tremendous amount of heat may be supplied, neither the liquid water nor the vapor rising therefrom is subjected to a temperature rise so long as the vapor is allowed to escape freely. A certain amount of heat is needed for the transformation of the water from the liquid to the vaporous state, that required for each pound transformed being about 966 times the amount which will raise the temperature of the same weight of liquid water 1 deg. fahr. This heat is made latent; i. e., it no longer has the power to effect a temperature change.

The purpose of air conditioning is the control of the effects of air on persons and materials.

Liquid water is changed to a vapor at temperatures far below the boiling point of water, but in all cases and under any circumstances the necessary number of heat units must be transformed and made latent. If the water and the air have the same temperature, and no heat is added from any other source, the heat of vaporization will be taken from the air.

It must be remembered that these heat units, while lost from the nitrogen and oxygen molecules of the air, are retained in the resulting mixture of air and water vapor. The point significant in connection with air conditioning —or in connection with even the crudest methods of heating and ventilating—is that this transformation of heat is always inevitable when water is available for evaporation into air, unless the air has already parted with its excess heat and the mixture of air and water are already at the point of heat equilibrium. This point may be termed the point of adiabatic saturation of the air.

It will be seen, then, that, as stated in a former paragraph, air does not "absorb" moisture as a sponge absorbs water. When we speak of dry air as robbing damp substances of their moisture we are not correctly describing the phenomenon. Perhaps we could more justly accuse the water of pillage, for the fact is that the liquid, because of its superior heat-holding power, actually takes heat from the air in exact ratio to this superiority, as has just been shown.

Control Both Temperature and Evaporation—Also Air Movement

We are, then, actually concerned not only with the loss of moisture from the skin and mucus membranes of the human animal, and from the external and internal surfaces of hygroscopic substances containing excess moisture, but with the loss of heat from these bodies by reason of its appropriation by the water vaporized. Both in industrial work and in heating and ventilating for human comfort we can control the actual effective conditions only by controlling both the temperature and the evaporative factor of the air used.

Even when we fix the temperature and the percentage of relative humidity of the air introduced into a room, we will fall short of our end unless we also control air movement. Ordinarily, any body absorbing heat from air having a relative humidity less than 100 per cent is surrounded with a stratum of air the relative humidity of which is increased, often to the point of saturation. A glass of iced water in calm air will quickly absorb enough heat to bring a stratum down to its dew-point temperature, and water vapor will be condensed on the outer surface. The latent heat appropriated by the water when vaporization occurred is given up with condensation, and in this case it is absorbed by the cold water.

But in heating and ventilating work the phenomenon of heat recovery is not a factor, though when we cool for comfort, we do make use of this process, employing cold water as a means of actually removing heat from the room. For, as already stated, the vaporization of moisture into air does not remove heat from the mixture of air and water vapor.

The human body is so made that a certain amount of evaporation from the skin and mucus lining of nose, throat and lungs is highly desirable, especially when surrounding temperatures approach that of the body. The research laboratory of the A. S. H. & V. E. has determined that a temperature above 71 deg. fahr. produces discomfort unless some evaporation is occurring, which means that for a person normally clothed an effective temperature of 71 deg.—some 27 deg. below the body temperature—will just about allow the dissipation of a sufficient amount of body heat, by virtue of the temperature head, to produce comfort in virtually calm air.

However, much higher room temperatures are comfortable when evaporation of body moisture is facilitated. This facilitation is brought about in two ways, both tending to accomplish the same result; namely, the lowering of the temperature of the air affecting the body toward the wet-bulb temperature of the room air. To produce evaporation, it is essential, of course, that the air used be deficient in moisture, or, more correctly speaking, that it be able to give up heat to water in coming to a heat equilibrium. Primarily, then, its percentage of relative humidity must be below 100 per cent. For example, it is shown by the Thermometric Chart of the A. S. H. & V. E. that with an observed room temperature of 78 deg. and a relative humidity of 40 per cent an effective temperature of approximately 71 deg. was still maintained without an appreciable movement of air.

With a room temperature (dry bulb) of 78 deg. and a relative humidity of 50 per cent the wet bulb temperature is 62 deg. Though it is stated that there was no air velocity, there was either sufficient air movement to displace a portion of the stratum between clothing and skin, or else the evaporation into the air breathed was sufficient to give a cooling effect equal to that produced by a temperature 7 deg. below the dry bulb and 9 deg. above the true wet-bulb temperature. But the significant point is that when the room air was moved over the body, still normally clothed, with a velocity of 700 ft. per minute, the effective temperature dropped to 65 degrees —to within 3 degrees of the room wet bulb!

Considered on the basis of wet-bulb depression (which with 78 deg. dry bulb and 62 deg. wet bulb is 16 degrees)

the effective temperature might be said to approach the wet bulb with an efficiency of 81 per cent when the velocity of the air reached 700 ft. per minute.

Certainly the phenomenon of evaporative cooling upon the surface of the human body is not analagous with that considered in the "Carrier Laws." Since the body contributes heat as well as moisture to the surrounding air the process is isothermal, rather than adiabatic. Moreover, since the amount of moisture presented by the skin and the membranes is not constant, it is not possible to calculate the actual temperature which will obtain in the stratum of air in contact with the body. The Thermometric Chart to which reference is constantly being made is based upon comparative sensations of heat, which are necessarily empirical. There is no power known to man by which a temperature lower than the wet-bulb temperature of the air can be obtained, for the wet bulb represents the sum total of the heat, both sensible and latent. The dry bulb may be lowered to the wet bulb by the transformation of sensible to latent heat, but when this heat equilibrium is reached no further transformation is possible.

Thus, if the air within an enclosure has an observed temperature of 78 deg. and a relative humidity of 40 per cent, the temperature may be lowered by heat metamorphosis (not heat removal) to the wet-bulb temperature, which is 62 deg. If any portion of this air is brought to a lower temperature it must be by the actual removal of heat.

However, an examination of the A. S. H. & V. E. Thermometric Chart will show that the sensation of a temperature far below the room wet bulb results from the impartation of velocity to so-called saturated air.

For example, it is shown that an effective temperature of 71 deg. results from an observed temperature of 71 deg. with a wet bulb of the same height. Such a combination of temperatures denotes complete heat equilibrium between air and water, and is usually termed "full saturation of the air"; i. e., humidity 100 per cent. Obviously no further heat metamorphosis can be accomplished, and therefore no further evaporation can occur adiabatically.

Yet it will be seen that an increase of air velocity to 300 ft. per min. produces the sensation of 66 deg. air on the body, while 700 ft. velocity is said to provide an effective temperature of about 60.5 degrees. This temperature, being more than 10 deg. below the actual wet bulb of the air, is certainly only comparative. It produces about the same sensation of comfort (or discomfort) as would still air having a temperature of 60.5 deg. and a relative humidity of 100 per cent, or as would a combination of 75 deg. dry bulb, 46 deg. wet bulb, 700 ft. velocity, and zero percentage of relative humidity!

The facts must be that because the body is giving out heat which tends to produce temperature equilibrium the processes carried out in the immediate vicinity of the body are more or less isothermal, which is to say that the heat contributed by the body, while tending to produce temperature equilibrium, may more or less inhibit the attainment of heat equilibrium as manifested in connection with adiabatic saturation—more if the heat emanating from the body is largely sensible, and less if it is largely latent.

Effective Temperature

But in addition to the isothermal aspects, the proposition has still another complication. A wet thermometer gives a true measure of the total heat of air, and records the temperature at which transformation of sensible to latent heat is completed, by virtue of the availability of liquid water for evaporation in close proximity to the bulb. If the supply of water is deficient the reading will be incorrect, for adiabatic saturation occurs only when heat equilibrium is established. So also will any body in contact with free liquid water respond. If unaffected by the introduction or removal of heat into or from the mixture of air and water vapor, the diminution of the "wet-bulb depression" (by the lowering of the dry-bulb temperature) will be influenced by the availability of liquid water. Thus, the human body that perspires with difficulty will react in a manner different from another the sweat glands of which are particularly active. One person may be fairly comfortable in a draft of 500 ft. per minute velocity with a temperature-humidity combination of 75 deg.—42 per cent because a deficiency of available moisture may inhibit evaporation and hold the sensation of warmth above the temperature determined as effective for average persons under those conditions; namely, about 63 deg., while another, whose perspiration is profuse, may experience a feeling of chilliness because the stratum of air effecting his skin may actually be brought nearer the true wet bulb temperature of the air, which is 60 deg.

Whether in industrial work in which the materials processed are capable of contributing liquid water for vaporization, or in the conditioning of air for human comfort, there are two very important considerations. One is the true wet-bulb temperature effective in the strata adjacent to the bodies, and the other is the actual relation of the dry-bulb to this wet-bulb temperature. The first is determined absolutely by the total heat of the mixture of air and water vapor which we may term "atmospheric air," the other depends upon the original wet-bulb depression (or dew point), the amount of water available for vaporization and the movement of the air. This is to say that a body which is neither producing nor appropriating heat will react exactly as will the bulb of a wet thermometer if means for supplying the necessary water and for furnishing an adequate supply of air are provided. The final effect of these conditions may be calculated with some exactitude by means of a chart prepared by Carrier and Lindsay in connection with experimental determination of the percentage of error from true adiabatic saturation temperatures occurring in the observed wet bulb readings at velocities ranging from zero to 2,000 ft. per min.

Problems Not Simple

But the problems confronting the air conditioning engineer are seldom so simple. Adiabatic phenomena are virtually non-existent in even the most rudimentary problems of heating. Unless we take into full account the matters of heat and moisture gain or loss, giving due consideration to both temperature equilibrium and heat equilibrium in connection with every object affected by our procedure, we cannot even control the effective temperature conditions which will produce a sensation of comfort or discomfort in the human body, or the actual

temperature and the moisture content of certain materials being processed.

It has been said that the question of the desirability of "artificial humidity" is one for the medical fraternity to answer. I seriously question this. While many eminent physicians and biologists have expressed themselves as favorable to the maintenance of a comparatively high percentage of relative humidity within enclosures occupied by human beings, in most cases the evils of dry air seem to be but half recognized.

In a former paragraph it was stated that we are probably somewhat inexact when we speak of air as robbing certain substances of moisture. It appears more likely that the water itself is the aggressor, and that by virtue of its superior power it appropriates heat originally contained in the dry air. Unquestionably the deprivation of the mucus linings of the respiratory organs of some of the moisture provided by nature is serious enough, but the fact that this loss of moisture is also accompanied by a rather tremendous loss of heat seems to have been

Flow of Fluids in Pipes

THE accompanying chart for determining the capacities of various sizes of pipe in pounds of steam per hour and gallons of liquids per minute is reproduced through the courtesy of Paulsen Spence, Spence Engineering Co., Inc., New York, N. Y. The left-hand section of the chart refers to free air per minute at the top and to pounds of steam per hour at the bottom. The right-hand section of the chart is for use to determine the flow of liquids in gallons per minute.

In order to use this chart it is necessary to assume a desired velocity for the pipe. For steam, Mr. Spence recommends a velocity of 3,000 F.P.M. in small pipes up to 8,000 F.P.M. in large pipes. For air he recommends a velocity of approximately one-half of this amount. For water he recommends a normal velocity of from 100 to 200 F.P.M., depending on the size of the pipe. There are some conditions where higher velocities can be used, but the above recommendations are safe for most all services, he believes.

As an example of how to use this chart, Mr. Spence explains how to determine the amount of steam that will flow through a 4-in. pipe at 100-lb. pressure. For a 4-in. pipe he recommends 4,000 F.P.M. At 100-lb. pressure at 1,000 F.P.M., a ¼-in. pipe will pass 10.9 lb. per hour. From the factors given it is evident that a 4-in. pipe is 122 times larger than a ¼-in. pipe (area for area), and a 4,000-ft. velocity is 4 times faster than a 1,000-ft. velocity. Therefore, $10.9 \times 122 \times 4 = 5320$ lbs. per hour.

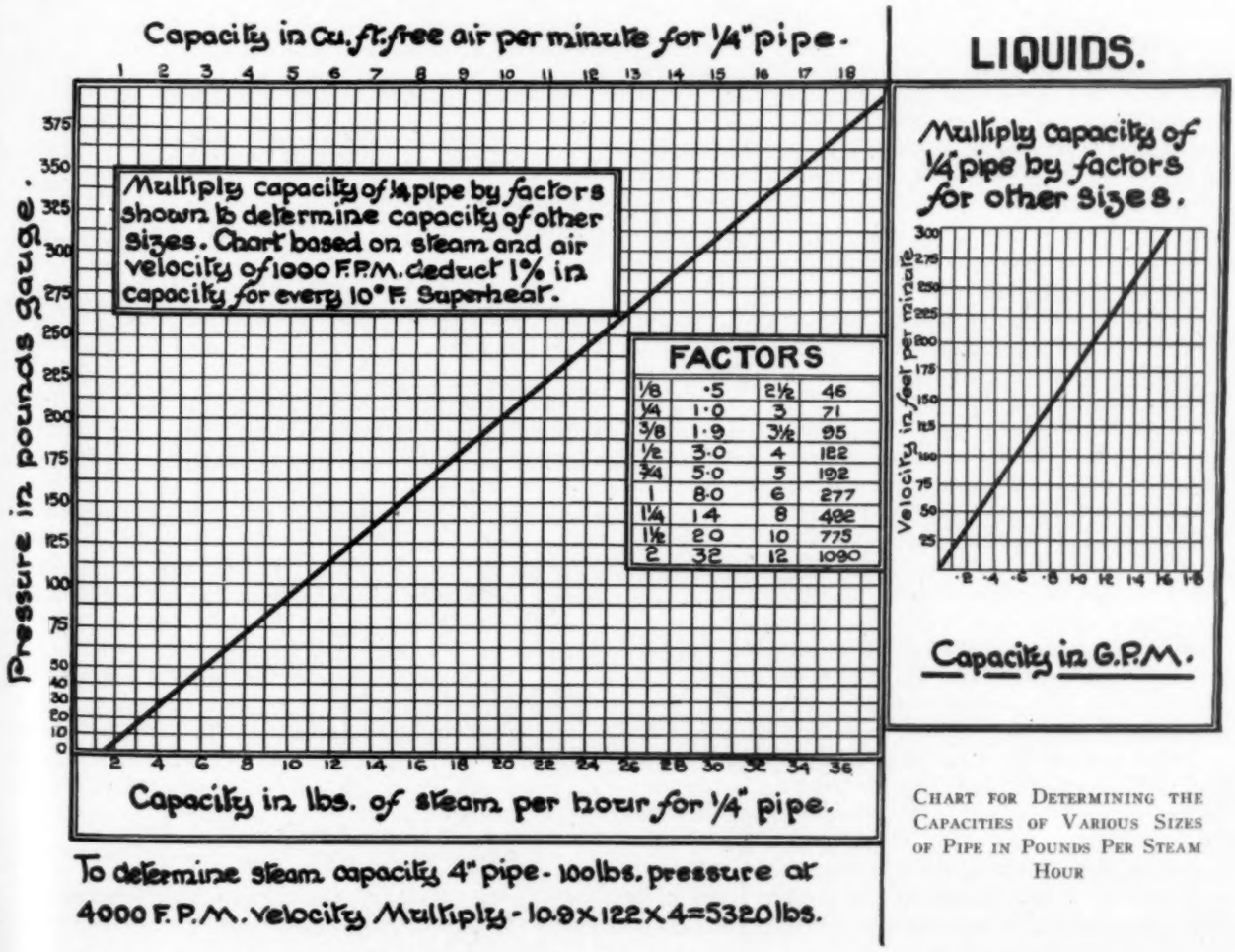

Capacity in cu. ft. free air per minute for ¼" pipe.
Pressure in pounds gauge.
Multiply capacity of ¼ pipe by factors shown to determine capacity of other sizes. Chart based on steam and air velocity of 1000 F.P.M. deduct 1% in capacity for every 10° F. Superheat.
FACTORS
⅛ ·5 2½ 46
¼ 1·0 3 71
⅜ 1·9 3½ 95
½ 3·0 4 122
¾ 5·0 5 192
1 8·0 6 277
1¼ 14 8 492
1½ 20 10 775
2 32 12 1090
Capacity in lbs. of steam per hour for ¼" pipe.
To determine steam capacity 4" pipe - 100 lbs. pressure at 4000 F.P.M. velocity Multiply - 10.9×122×4=5320 lbs.
LIQUIDS.
Multiply capacity of ¼ pipe by factors for other sizes.
Velocity in feet per minute
Capacity in G.P.M.

CHART FOR DETERMINING THE CAPACITIES OF VARIOUS SIZES OF PIPE IN POUNDS PER STEAM HOUR

given scant consideration. It must be remembered that every pint of water lost from the body by the evaporation of perspiration or of the mucus secretions involves the expenditure by the body of heat sufficient to raise the temperature of a gallon of water about 120 degrees!

Obviously, the loss of so much heat from the comparatively small surface area presented by the respiratory tract is certain to result in a sharp lowering of temperature. To this nature will respond with a rush of warm blood and congestion may be the result. Certainly serious consequences are likely to follow the subjection of the body to air possessing a high evaporating power, but certainly these are due fully as much to a loss of temperature as to a loss of moisture.

And, after all, just how shall we define the term "artificial humidity"? Isn't it true that a condition of unnatural, or "artificial," humidity is brought about when air is heated without due consideration to the control of the heat metamorphosis that is certain to occur when it is brought into contact with free moisture?

Skin Is Man's Heat Regulator

My good friend, Esten Bolling, after reading the book, "The Human Body," by Logan Clendening, M. D., points out in the latest issue of "The Weather Vein" (Vol. 9, No. 1), that ordinarily respiration accounts for only about 20 per cent of the heat losses of the human body. Usually the skin is man's great heat regulator, accounting, by conduction, radiation and evaporation, for nearly 80 per cent of the body heat dissipated.

It must not be forgotten that we never "heat" the human body. Its temperature is maintained by the body processes, and it is always expending heat. What we try to do is to control this expenditure. In winter we bring about its diminution by employing the insulating properties of clothing and by adding heat to the air surrounding the body; in summer we endeavor to increase it by discarding heavy clothing and surrounding the body with air that will readily absorb heat.

When the temperature of the surrounding air is not very high a large part of the heat expenditure is brought about by radiation and conduction, and the sweat glands of the skin are comparatively inactive. With heavy clothing the stratum of air between the clothing and the skin must soon become heavily impregnated with moisture, and when the air movement is insufficient to displace this with a mixture carrying some superheat, evaporation is virtually nil. But the respiratory organs are not protected by clothing, and the secretion of moisture upon them is not dependent upon high temperature. When air having a high evaporative power; i. e., a low percentage of relative humidity, is breathed, vaporization of moisture, with the concomitant lowering of temperature, is certain to occur. And we must not fail to remember that the average amount of air breathed by a normal person in the course of 24 hours is about 25 lbs.

"It is remarkable, then," says Mr. Bolling, "that so many voluminous (and usually absurd or faddist) treatises upon food, or diet, have been written and pounced upon by the public, whereas the average person knows almost nothing about that magic fluid, air, without which they cannot exist so long as five minutes. Or rather it would be remarkable were it not for the lamentable fact that the human being is the only animal with sufficient mental capacity to make grievous mistakes!"

In my treatment of this subject I have purposely stressed the thermal phase, believing that this is the least understood. However, when it is realized that the total amount of air breathed in a day actually weighs at least four times as much as the food consumed, I think it will be conceded that in the matter of purity and from the standpoint of efficiency as a supporter of combustion, the air is at least as important as food.

Air is not nearly as mobile as is sometimes believed. When we exhale carbon dioxide gas (the product of complete combustion) we almost surely again inhale some of it unless adequate provision for its removal is made. A copious supply of fresh air will take care of this provision, for the great out-of-doors, even in cities, is not usually unduly depleted of oxygen; but it is not always easy to accomplish this end without encountering the thermal complications mentioned above.

And what shall be done in summer, when nature provides effective temperature conditions which are unable to absorb excess body heat by the combined processes of conduction, radiation and evaporation? "Natural" humidity is usually too high, at least within buildings where people are gathered, for every breath exhaled and every grain of perspiration evaporated from the skin tends to increase it. Actually the high percentage of relative humidity is the result of an unnatural condition, and might therefore be termed "artificial." The removal of heat from the mixture of air and water vapor, which means essentially the removal of some of the moisture if we are to preserve the evaporative property of the air, will re-establish an effective temperature condition that will produce comfort, or a "natural" condition.

Air Purity

On the matter of purity it is not necessary to dwell. Who has not seen a shaft of sunlight through a supposedly immaculate room reveal thousands of floating dust particles? The origin of these is perhaps not always easy to trace, but one can be sure that many of them would not be in existence if the moisture-heat relation of the room air were ideal. It is certain that dust formation is greatly reduced by the maintenance of correct humidity, and that this will also effectually prevent the accumulation of static electricity. Moreover, there is ample proof that disease germs find dust particles ideal conveyances.

Air purity is a certain concomitant of that other phase of air conditioning which is necessary to the establishment of the proper moisture-heat relation in a mixture of air and water vapor used as a conveyor of heat and oxygen. Whether the objective be humidifying and heating in winter or dehumidifying and cooling in summer, actual control can be accomplished only by the absolute fixing of the dew point as the desired conditions require. A few scattering drops of water falling through the air will not do this, nor will such inefficient methods remove the dust, soot, spores and bacteria which are always present in unwashed air.

Duplicating Nature's Most Benign Moods

Once manufactories sought localities where "natural" conditions of temperature and humidity were most favor-

able to their processes. Fine silk cloth was woven in caves, and by hand power, because only by this means could the favorable "natural" conditions be in a measure preserved. Once large gatherings of human beings were held in groves, because only in such places were the heat-and-moisture-equilibrium forces of nature sufficiently potent to combat the "artificial" conditions arising from the aggregating of a large number of people.

Today, if we suffer the inconveniences, discomforts and monetary losses of improper atmospheric conditions within the buildings we erect, we are fair enough to recognize that we, and not nature, are at fault. For engineering science is now able to duplicate nature's most benign moods within any enclosure, regardless of the density of the human mass or any other "artificiality" of the situation. If our schools, our offices, our factories and shops—even our homes—fall short of the most perfect of "natural" conditions it is often due more to ignorance than to either penuriousness or impecuniosity. This applies, not alone to the splendid cinema palaces, the magnificent sky-scrapers, the stupendous manufacturing plant or the pretentious mansion of the millionaire, but to the broad field in which you and I and other men of modest means live and work and recreate.

A. S. H. V. E. Holds Mid-Summer Meeting in Canada

For the first time in its history, the American Society of Heating and Ventilating Engineers met outside the borders of the United States, when, on the occasion of its 35th semi-annual meeting, June 25 to 28, it accepted the invitation of the Ontario chapter to convene at Bigwin Inn, Lake of Bays, an island resort of rare beauty 160 miles north of Toronto. As Thornton Lewis, president of the society, stated, engineering is international, and it is quite fitting that the Canadian members be visited. They, in turn, fulfilled all expectations with an excellently arranged business program and means of entertainment that more than justified the enthusiastic resolutions of thanks and congratulations offered at the final session.

M. Barry Watson was general chairman of the committee on convention arrangements. Arthur Leitch was in charge of entertainment, M. F. Thomas of reception, A. J. Dickey of finance, E. B. Sheffield of transportation and Edward M. Dolan of publicity.

While election of officers will wait for the annual meeting in January, an indication of the new slate was given in the nominating committee's report, naming L. A. Harding, president; W. H. Carrier, first vice president; F. B. Rowley, second vice president, and Cecil W. Farrar, treasurer.

The papers presented at this meeting have appered or will appear in the Journal Section of Heating, Piping and Air Conditioning. One of the outstanding activities of the meeting was the work of the committee appointed by the society to draft a code for testing and rating unit heaters. Unit heater manufacturers sponsored tests at the University of Kentucky by Professor L. S. O'Bannon, which were aimed to check methods and results obtained in the research laboratories of individual manufacturers, and these tests confirmed such methods and results to a degree which enabled the unit heater people to adopt a code. However, as D. E. French, chairman of the committee, explained, it was decided that the society should not be asked to adopt it until it had been put to practical test in the next six months. Therefore, it will be presented at the January meeting with any modification that may be necessary to make.

The report of the committee on the code for heating and ventilating garages was presented, and the code adopted. E. K. Campbell, Kansas City, Mo., chairman of this committee, was to have presented it, but he sustained injuries in an automobile accident on his way to the convention, which prevented his arrival.

The code for rating low pressure heating boilers, as drafted by the National Boiler and Radiator Manufacturers' Association, was adopted by the society at this meeting, also, to the evident relief of L. A. Harding, who was chairman of the committee on the interpretation of this code and who mentioned in his report that this was a twenty-five year old question that was finally being solved.

Meetings were held from 9:30 to 12:30 each morning, leaving the members free to play golf or enjoy other forms of diversion which the island offered in the afternoon. The banquet was held the first night and a masquerade ball the second.

National District Heating Association Holds Twentieth Annual Convention

On June 11, 12, 13 and 14, members of the National District Heating Association met at the Hotel Statler, Detroit, Mich., for their twentieth annual convention. Every phase of this industry—operating, distributing, rates and regulations, meters, public relations—was covered in committee reports and round table discussions, and, in addition, the broader trends of heating in general, research, higher pressures and temperatures and education were considered in addresses by men high in their respective fields, such as Professor A. C. Willard, of the University of Illinois, Sabin Crocker, chairmen of various committees working on piping standards and codes, Professor C. F. Hirshfeld, of the Detroit Edison Co., Dean A. A. Potter, of Purdue University, and J. Rowland Bibbins, of Washington, D. C.

The distribution committee paid considerable attention to the welding of pipe lines in its report and, in addition, presented valuable data on valves, flanges and fittings, on expansion joints, on bolts, on insulation, on conduits, on manholes and on steam traps. High and low pressures, with their distribution problems, were discussed.

Professor Willard presented a paper on the efficiency of radiators with various types of enclosures, giving data which supported the fact that enclosures of certain types increase radiator efficiency.

Professor Hirshfeld and Dean Potter both called attention to the trend in central stations and in in-

dustrial plants toward the installation of equipment which worked with pressures and temperatures far higher than those generally accepted as operating practice in past years. They felt it necessary that district heating engineers understand what this trend means in the possibilities it affords the isolated plant to "skim power off the top" of the steam it is generating for heating and process purposes, for it has proved its economy in a number of cases and it changes the picture of purchasing power.

The Detroit Edison Company was a fine host to the visiting members. Its representatives, led by J. H. Walker and E. E. Dubry, left nothing undone to make the hours outside of the convention hall interesting and entertaining. It arranged inspection trips and planned most of the entertainment.

J. C. Butler, Chicago, was elevated to the presidency of the association for the coming year. Mr. Butler is with the Illinois Maintenance Co. in Chicago and has been active in association work for the past ten years.

Other officers elected were L. S. Smith, Rochester, N. Y., first vice-president; W. W. Stevenson, Pittsburgh, Pa., second vice-president; A. D. Leach, Portland, Ore., third vice-president. Members of the executive committee will be John W. Meyer, Philadelphia, Pa., retiring president; E. E. Dubry, Detroit; J. E. Seiter, Baltimore. D. L. Gaskill, Greenville, Ohio, is secretary-treasurer of the association.

Sixteenth Spring Meeting of the American Society of Refrigerating Engineers

One hundred and seventy-six members and guests attended the sixteenth spring meeting of the American Society of Refrigerating Engineers at Pennsylvania State College, State College, June 20, 21 and 22. In the five technical sessions, twenty-one technical and merchandising papers and addresses were presented. An exhibit of products and mechanical equipment used in the refrigerating industry was provided by twenty-six concerns. Entertainments were provided including trips in the Alleghany mountains.

The papers, addresses and discussions related to design of ice making plants, refrigeration research, climatic influences affecting refrigeration design, electrical measuring instruments used in refrigeration research and practice, present practice in heat transmission measurements, refrigeration in its relation to transportation and refrigerator merchandising.

Among those who took active part in the convention were F. S. Strike, consulting engineer, New York City; C. T. Baker, consulting engineer, Atlanta, Ga.; George Lange, vice president, American Ice Co., New York; C. F. Belshaw, George B. Bright Co., Detroit, Mich.; C. Z. Rosencrans, head of electrochemical research, Leeds & Northrup Co., Philadelphia; Prof. F. G. Heckler of Pennsylvania State College; B. H. Coffey, consulting engineer on cooling towers, New York City and David L. Fiske, secretary of the society.

In a joint session of the American Society of Refrigerating Engineers and the American Society of Mechanical Engineers, J. W. Roberts of the Pennsylvania railroad; Eugene F. McPike, manager of the perishable freight service division of the Illinois Central railroad; Dr. Lon A. Hawkins; A. W. Oakley, Merchants Refrigerating Co., New York City, and Dean R. L. Sackett, in charge of engineering at Pennsylvania State College, took part.

In one session, railway refrigeration was discussed by E. A. Sweeley of the Fruit Growers Express, Alexandria, Va.; F. G. Grimshaw, works manager, Pennsylvania railroad, Altoona, Pa.; R. W. Waterfill, Carrier Engineering Corp., Newark, N. J.; C. P. Goree, representing Frick Co. at Atlanta, Ga., and others.

Merchandising and other features of refrigerators were discussed by R. F. Frazier, Tennessee Furniture Co., Chattanooga, Tenn.; F. M. Cockrell, Detroit, Mich.; Miss Mildred Porter, bureau of home economics, department of agriculture, Washington, D. C.; Dr. E. F. Mueller, physicist, bureau of standards, Washington, D. C.; H. D. Edwards, vice president of the society and works engineer of the Union Carbide & Carbon Co., New York City.

The president of the society is Prof. Arthur J. Wood, head of the department of mechanical engineering of Pennsylvania State College.

Form Boiler Institute

The Institute of Boiler and Radiator Manufacturers was formed June 6, 1929, in New York City, and has succeeded the National Boiler and Radiator Manufacturers' Association as the central organization of that industry. The Institute will promote the interests of the boiler and radiator industry along lines where concerted action is necessary. An unfair competition bureau will be maintained by the Institute which will investigate any complaints charging unfair methods of competition by members.

The officers of the new manufacturers' organization are H. T. Richardson, chairman; Grant Pierce, vice chairman; and Frederick W. Herendeen, secretary and treasurer. The members of the executive committee are H. T. Richardson and Frederick W. Herendeen, ex-officio members; M. J. Beirn, Grant Pierce, E. E. McNair, Max D. Rose, and A. H. Schroth.

Colonel William J. Donovan will act as general counsel for the Institute. Colonel Donovan was formerly assistant to the attorney general of the United States.

The following companies are members of the Institute:

Abendroth Bros.
American Radiator Co.
Molby Boiler Co., Inc.
Central Radiator Co.
Columbia Radiator Co.
Dunkirk Radiator Corp.
Utica Radiator Corp.
Hart & Crouse Co.
International Heater Co.
Landon Radiator Co., Inc.
National Radiator Corp.
United States Radiator Corp.
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Heating·Piping
and Air Conditioning

American Society of Heating and Ventilating Engineers JOURNAL SECTION

1895

JULY 1929

Material in this Section prepared by Publication Committee: A. C. Willard, *Chairman*; N. W. Downes, and W. A. Rowe. : A. V. Hutchinson, Manager of Publications

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Determining the Quantity of Dust in Air by Impingement*

The results of co-operative research between the A. S. H. V. E. and the University of Minnesota

By F. B. Rowley[1] (Member) and John Beal[2] (Non-Member), Minneapolis, Minn.

ONE of the major problems confronting the Technical Advisory Committee on Air Filters has been that of determining the quantity of dust in the air. Many methods have been suggested and tried out, a part of which have been more or less successful. While several of the methods have some merit, it has not been a simple problem to select one which has been acceptable to the industry as a whole. For those methods which have been found to give consistent results, it has generally been necessary to employ rather delicate and expensive apparatus which can only be handled by trained operators.

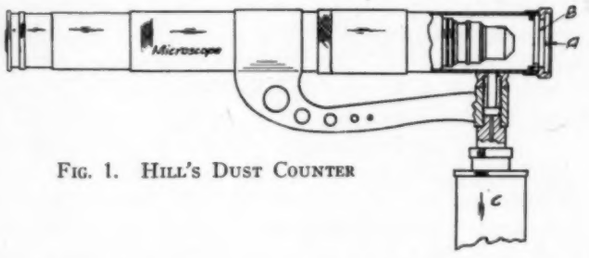

FIG. 1. HILL'S DUST COUNTER

To be acceptable, a method should not require apparatus which is out of the reach of the average engineer. It should be applicable to the average air condition and should give dependable results. To fulfill the latter requirements, it is not necessary to have absolute results, but if the instrument does not record on the absolute basis, the relation of the results obtained to the absolute quantities should be the same for like conditions of air. There are, probably, several methods which may be found to fulfill these requirements, but thus far none have been generally accepted.

It is not necessary that all of the existing methods be approved or disapproved, but rather that some of the most promising ones be investigated with the idea of selecting at least one which may be used as a standard or as a tentative standard in order that results obtained by different engineers may be on a comparable basis.

The first research work conducted was with the AA dust determinator. The results of this work were reported in a paper entitled A Study of Dust Determinators, presented at the society's Semi-Annual Meeting, 1928, and published in the JOURNAL, October, 1928, p. 741. These researches indicated that this method has promise and undoubtedly could be refined to a point where consistent and reliable results may be obtained. The recent studies which have been made and the results of which are reported in this paper relate to the impingement type of dust determinator. This method has some advantages, such as simplicity, convenience to operate, and also the possibility that the operator may get a better idea of the quality of dust when examined under the microscope.

In general, the apparatus consists of a nozzle through which the air for test is drawn at high velocity by a pump. The stream of air strikes a plate which is usually covered with some viscous material. The dust particles striking the plate remain and may be examined under a microscope or by other means.

With this type of dust counter, there are several questions which immediately arise:

1. What is the limiting size of the particles which should be considered?
2. What proportion of dust is actually taken from the air? This is affected by such factors as:
   - *A.* The distance of the nozzle from the plate.
   - *B.* The velocity at which the air is brought against the plate.
   - *C.* Shape and position of the nozzle.
   - *D.* The density and size of particles of the dust.
3. Is the proportion of dust consistent and uniform for samples of the same air when treated in the same manner?

In the first part of the investigation the Hill dust counter was used, one model of which is illustrated in

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* For presentation at the Semi-Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Bigwin Inn, Lake-of-Bays, Ontario, Canada, June, 1929.

Fig. 1. This consists of a nozzle *A*, a glass plate *B* and a pump *C*. The nozzle is set at a definite distance from the plate and the air is drawn through it by a plunger pump. The samples of dust taken by this method are counted under the microscope, which in this case is an integral part of the instrument. The microscope furnished with the apparatus magnifies to 80 diameters. After some experience with the instrument, it was found that the operator could count with a reasonable degree of certainty the particles visible under the microscope. There was, however, some question as to the lower limit of dust particles to consider. When these same samples were put under a high power microscope, only a small portion of the sample could be observed at one time and there was also present a much greater number of extremely small particles which would make the process of counting impossible unless these particles were eliminated. There are two plausible reasons suggested why these should be eliminated:

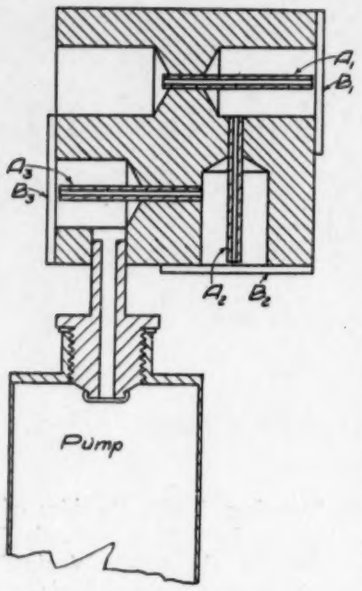


Fig. 2. Counter, With Three Nozzles in Series

First. That the number of these particles is proportional to the number of larger particles so that a count of the most distinguishable ones furnishes a relatively correct count for the whole sample.

Second. The size of these particles may be below the size which is of any interest in air filtration work.

In considering these two reasons it is difficult to find a basis supporting the first suggestion. On the other hand, the second seems to be a necessary conclusion. If the dust particles decrease in size indefinitely, there must be some lower limit beyond which it is impractical to go. This viewpoint might be considered to be supported by the work of Whitlaw Gray and Speakman (*Proceedings, Royal Society,* A102, 615-27, 1923), who determined the concentration, average size, and average mass of particles of zinc oxide suspended in air. They determined the number of particles by direct observation with an ultra-microscope, and the mass by filtering the air and weighing the filtrate on a micro-balance. Their results show that in a diluted cloud of zinc oxide smoke there are in the neighborhood of 1,000,000 particles per cu. centimeter, or about 3,000,000,000 particles per cu. ft. The possibility of having such a high concentration of extremely minute particles seems to indicate that either these small particles must be disregarded in air filtration work or that the idea of separating the particles by impingement and counting them must be given up.

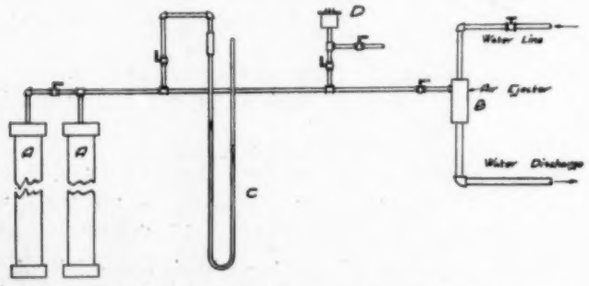


Fig. 3. Constant Velocity Dust Determinator

In the preliminary tests carried out by the Hill dust counter, it was found that by counting only those particles which were large enough to appear under the microscope as a definite black point, reasonable check results could be obtained. The best results seemed to be given with 200 to 300 particles collected on the glass. It was also found that air with low dust content gave the most consistent results. The results obtained by the various types of Hill dust counters will be discussed later in the report.

For the purpose of studying the various factors which affect the proportion of dust taken out of the air by the impingement method, two special pieces of apparatus were constructed. The first, shown by Fig. 2, was a device which caused the air to be passed through three consecutive nozzles and impinge against three consecutive plates. The nozzles are shown by letters, A_1, A_2, and A_3, and the plates, B_1, B_2 and B_3. The air from the last nozzle chamber discharges into a pump chamber. The second piece of apparatus is illustrated by Figs. 3, 4 and 5. Fig. 3 is a diagrammatic view of the apparatus which consists essentially of two vacuum tanks *A*, a water ejector *B* for creating a vacuum, a mercury manometer *C* and a dust sampling chamber *D*. The dust sampling chamber is shown in detail in Figs. 4 and 5, Fig. 4 being vertical, cross-sectional, and Fig. 5 a lower view with the dust plate in place. Referring to Fig. 4, *A* represents an air-tight chamber which is connected to the vacuum line, and *B* is a removable top which contains three nozzles, *C*. These nozzles are closed at their upper end by a spring operated valve *D* and project at their lower ends to a predetermined distance from the glass plate *E*. The glass plate is held in position by springs *F* and serves as a collector for the dust samples. The distance of the nozzle *C* from the plate *E* may be changed to suit the requirements. The cover *B* is held in place by atmospheric pressure and the smooth joint between *A* and *B* is sealed with vaseline. The object of the apparatus is to obtain a dust sample under conditions of uniform air velocity.

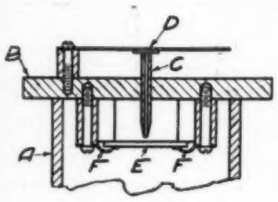
In operation the water ejector is used to pump the air out of the tanks, *A*, the vacuum in these tanks being measured by manometer, *C*. Since the tanks are of known capacity, the amount of air in them at any time may be measured by the pressure in the manometer tube or by closing off the ejector and opening one of the valves, *D*, Fig. 4, the amount of air passing through the nozzle may be determined by the change in pressure. From this process the velocity through nozzle may be calculated for different pressures and by adjusting the vacuum tanks to these predetermined pressures a dust sample may be taken at any given velocity through the nozzle. The volume of air for a test may be measured either by

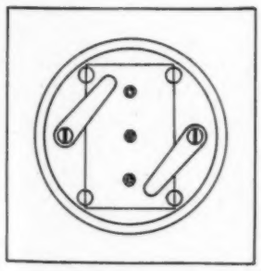
noting the time during which the valve is open or by calculating the increase of volume of air in the tanks by the manometer readings. This apparatus was used both for the single nozzle and for the nozzles in series as shown in Fig. 2.

In those tests which were conducted with three nozzles in series, two types of nozzles were used: *First,* those with square ends; *second,* those with sharp edges. The nozzles were all 0.05 in. in diameter and were set at various distances from the plate. It is evident that a long line of experiments might be conducted covering the size, shape and placement of the nozzle, but it is not necessary to know all of the details of this part of the problem in order to select satisfactory conditions. The size and shape of the nozzle and the velocity of air through it must be governed by the size of the sample required. Any combinations of conditions which can be readily duplicated, giving consistent samples uniformly distributed under the microscope, should be satisfactory.

The results of comparative tests between the square and sharp edged nozzle seemed to indicate that the latter gave the best results. The sharp edged nozzle was, therefore, used for the remainder of the tests. The first series of tests in which the three nozzles were used in series was made by drawing the air through with a plunger pump. The results of these tests are shown in Table 1. They showed that, with the nozzle set at 0.005 in. from the glass, as high as 94 per cent of the total dust was taken out at the first impingement. When this same air was tested with a single nozzle, a much higher count was obtained. The only reasonable explanation of this seemed to be that, since the same pressure drop was used across the three nozzles as across the single nozzle, the velocity through the three nozzles was necessarily much lower and reduced the amount of dust collected.

As it was impossible to change the velocity conditions with a pump method, the apparatus as described in Figs. 3, 4 and 5 was designed and built. In using the vacuum apparatus, it was desired to get both the amount of air used for a sample and the velocity of impingement. As stated before, velocity might be determined from volume and time or from the pressure across the nozzle and a calibration curve for the nozzle. The time required for a test is so short that it is difficult to take it accurately; therefore, the velocity was determined from the pressure. Since the resistance through the nozzle is greatly increased when the nozzle is set close to the plate, the velocity is also greatly decreased. It was, therefore, necesary to make a separate calibration for each setting of the nozzle.





FIGS. 4 AND 5. VERTICAL CROSS SECTION AND UNDER VIEW OF *D* IN FIG. 3

By setting the nozzles at different clearances from the plate and changing the velocity at which the samples were taken, it was found that the number of particles of dust collected increased with the velocity of air through the nozzle and decreased as the clearance increased. The curves of Fig. 6 show the results of a series of tests made to demonstrate these characteristics. Further consideration of the results obtained shows that there is a limit to which the decrease in clearance may be used for increasing the dust count. At 0.005 in. clearance, the resistance to the passage of air was so great that 200 ft. per second was the maximum velocity obtainable at full atmospheric pressure. At greater clearances much higher velocities could be obtained and the additional amount of dust collected in the sample by these higher velocities more than off-set the loss due to the greater clearance between the nozzle and glass. This illustrates the reason why with three nozzles in series 0.005 in. appears to give the best results. The resistance of the three nozzles in series is so high that the additional effect of reducing the clearance is comparatively small and a reduced clearance increases the dust collected in a greater portion than it decreases the velocity.

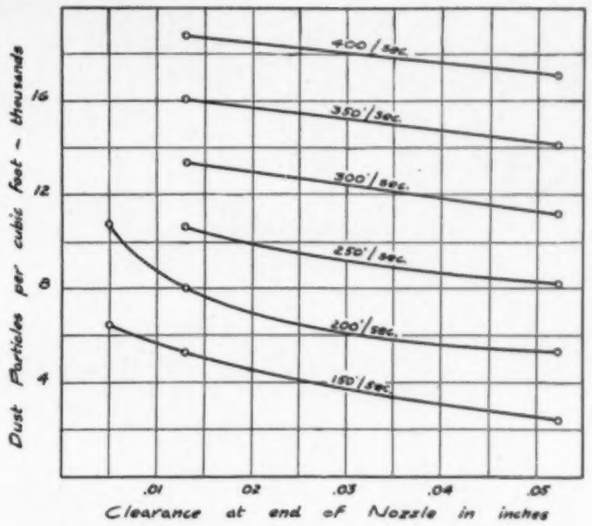


FIG. 6. EFFECT OF NOZZLE CLEARANCE AND AIR VELOCITY ON DUST COUNT

TABLE 1. THREE NOZZLES IN SERIES, DUST SAMPLES TAKEN WITH PLUNGER PUMP

	No. of Samples Average	Clearance Between End of Nozzles and Plates, Inches			Average Dust Part. per Cu. Ft.	Maximum Per Cent Variation from Average	Average Per Centage Retained on 1st Plate	Maximum Per Cent Variation from Average
		1st	2nd	3rd				
Square ended nozzles	7	0.005	0.005	0.005	2254	15.5	83.0	14.0
	3	0.010	0.005	0.005	7059	5.0	89.6	1.6
	8	0.016	0.005	0.005	2700	44.4	75.7	18.0
	1	0.025	0.005	0.005	7048		71.3	
1st Nozzle with sharp edged exit	4	0.005	0.005	0.005	2609	8.3	88.6	5.0
	4	0.005	0.005	0.005	6998	3.3	94.6	6.1
	6	0.010	0.005	0.005	2048	11.0	86.8	8.5
	4	0.016	0.005	0.005	1552	9.2	85.6	3.1

The results of a second series of tests, in which the

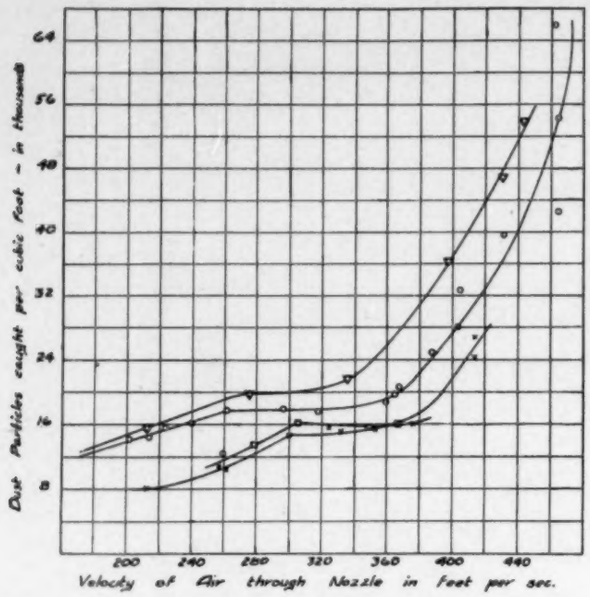


FIG. 7. EFFECT OF AIR VELOCITY ON DUST COUNT FOR DIFFERENT SAMPLES

air was drawn through three consecutive nozzles with the constant velocity apparatus, are shown in Table 2. In these tests the velocity through the nozzles was 250 ft. per second and the clearance was 1/16 in. These tests showed that 95 per cent of the total dust collected was retained on the first slide. The consistency of the percentage taken out indicates that it is not necessary to use more than one nozzle.

The influence of velocity on the number of particles collected was next more carefully worked out. All nozzles were set at the same clearance in order that a larger number of samples might be taken in a shorter time, thus partially eliminating the variation in the amount of dust contained in the air for the different samples. With the nozzle clearance of 0.015 in., the results as given in the curves of Fig. 7 were obtained. These curves are located differently due to the fact that the samples were taken on different days, and, therefore, with a different dust content in the air. They do, however, all show similar characteristics—that is, a general

TABLE 2. THREE NOZZLES IN SERIES. DUST SAMPLES TAKEN AT CONSTANT VELOCITY OF 250 FT. PER SECOND. NOZZLES SET AT 1/16 IN. CLEARANCE

Test No.	Slide No.	Dust Part. Collected	Per Cent of Total Retained on First Slide
1	1st Slide	over 600	
	2nd Slide	15	
	3rd Slide	6	
		Total 621	96.5%
2	1st Slide	over 1000	
	2nd Slide	48	
	3rd Slide	12	
		Total 1060	94.5%
3	1st Slide	over 800	
	2nd Slide	24	
	3rd Slide	3	
		Total 827	96.8%

increase in the dust count from 200 to 275 ft. per second with a flat portion between the range of 275 to 300 ft. per second from which the slope extends upward very rapidly. The points fall very consistently on the curves until the portion of rapid increase in count is reached, after which they show a considerable amount of variation. It will be noted that the samples were taken with three different nozzles which were supposed to be identical. Later work showed that there was a slight variation in the bore of one of these nozzles which gave it a slightly different characteristic. The same general characteristic is also shown in the curves of Fig. 8. These curves show that at lower velocities the count is much higher for the close setting of the nozzle tip to the glass, but that the limiting velocities are soon reached and from this point on the count is higher with a free discharge opening.

It was thought possible that the large number of dust particles collected at high velocities was due to the fact that as the velocity is increased many more of the smaller particles are precipitated to the plate. When counting the sample, it is extremely difficult to differentiate between the two sizes and the total number visible is the most practical count to be made for the sample. One series of tests was, however, run in which only particles above a certain size were counted. This was accomplished by comparing the particles to a spot in the field of the microscope which was estimated to be about 15 microns in diameter. The velocity was varied through the entire range and the results obtained are shown on

TABLE 3. NUMBER OF LARGE PARTICLES OF DUST DEPOSITED AT VARIOUS VELOCITIES

Velocity of Air Through Nozzle	No. of Particles Above 15 Microns in Size	Velocity of Air Through Nozzle	No. of Particles Above 15 Microns in Size
200	49	400	52
220	42	430	60
270	48	450	51
330	49	460	47
390	49		

Table 3. These results would indicate that the assumption is correct, although no sharply defined relation exists between the velocity and the smallest size deposited, for even at the slowest velocity many of the particles appear to be just as small as those at the higher velocities, although there were a great many more of the small particles at the higher velocities.

From the experiments thus far conducted, it is evident that the amount of dust taken out of a sample is affected by at least three factors.

A. Size and shape of the nozzle.
B. Distance of nozzle from sample plate.
C. Velocity of air through nozzle.

The size of the nozzle seems to be governed largely by the size of the sample desired. The shape is subject to further experimental work, but of the nozzles thus far tried the sharp edged nozzle appears to give the best results. The effect of distance between the nozzle and the glass plate depends somewhat upon the resistance to the

air flow, the effect being greater for small clearances. From the tests made, it would appear that 1/16 in. clearance gives reasonable results and it is a clearance from which wide variation need not be expected for small differences either way. This clearance was, therefore, selected for further experimental work. From the curves thus far shown, it is evident that velocity has a very great effect upon the amount of dust deposited and that some specific velocity must be maintained for comparative results. It is also evident that, under no obtainable conditions will all of the dust be precipitated from the sample; therefore, any results with this type of counter must be on a comparative basis. Under this condition those factors which affect a sample must be selected and fixed in some range within which it is possible to remain in practice. The particular values which are assigned to these variable factors do not appear to be of as much consequence as is the necessity for their standardization.

In order to determine the reliability of the impingement method when conditions are definitely controlled, many sets of tests have been run under fixed conditions. For the greater part of these tests a nozzle 0.05 in. in diameter and with 1/16 in. clearance from the collecting glass was used. Several series of samples were taken from the air in a large room. In each series the conditions of sampling were held constant and the time inter-

TABLE 4. SAMPLES TAKEN WITH VACUUM APPARATUS CLEARANCE=1/16 IN.

SERIES	SAMPLE NO.	VELOCITY FT. PER SECOND	DUST COUNT PARTICLES PER CU. FT.	PER CENT VARIATION FROM AVERAGE
A	1	300	23,800	+0.42
	2	300	24,050	+1.48
	3	300	23,200	+1.90
			Average 23,700	
	4	400	69,000	−1.8
	5	400	71,100	+1.2
	6	400	70,700	+0.6
			Average 70,270	
B	1	300	21,200	+7.90
	2	300	18,810	−4.23
	3	300	19,100	−2.80
	4	300	19,500	−0.76
			Average 19,650	
C	1	300	12,480	−2.82
	2	300	12,410	−3.40
	3	300	12,690	−1.18
	4	300	13,200	+2.64
	5	300	13,280	+3.36
	6	300	13,000	+1.18
			Average 12,843	
	7	400	42,800	+1.33
	8	400	42,800	+1.33
	9	400	44,900	+1.56
	10	400	41,200	−0.33
	11	400	39,500	−6.48
			Average 42,240	
D	1	300	9,600	−4.87
	2	300	9,480	+2.58
	3	300	8,520	−6.91
	4	300	9,240	+0.94
	5	300	8,930	−1.36
			Average 9,154	
E	1	300	29,800	−1.7
	2	300	27,100	−7.5
	3	300	30,800	+5.1
	4	300	28,300	−3.4
	5	300	31,100	+6.1
	6	300	28,900	−1.3
			Average 29,300	

TABLE 4. SAMPLES TAKEN WITH VACUUM APPARATUS CLEARANCE=1/16 IN.—CONTINUED

SERIES	SAMPLE NO.	VELOCITY FT. PER SECOND	DUST COUNT PARTICLES PER CU. FT.	PER CENT VARIATION FROM AVERAGE
E	7	400	84,900	+2.16
	8	400	75,600	−9.03
	9	400	82,900	−0.24
	10	400	86,600	+4.22
	11	400	87,000	+4.70
	12	400	81,600	−1.80
			Average 83,100	
F	1	300	3,160	+3.5
	2	300	2,980	−5.4
	3	300	3,250	+4.5
	4	300	3,180	+1.0
	5	300	3,270	+3.8
	6	300	3,200	+1.6
	7	300	3,000	−4.8
			Average 3,150	

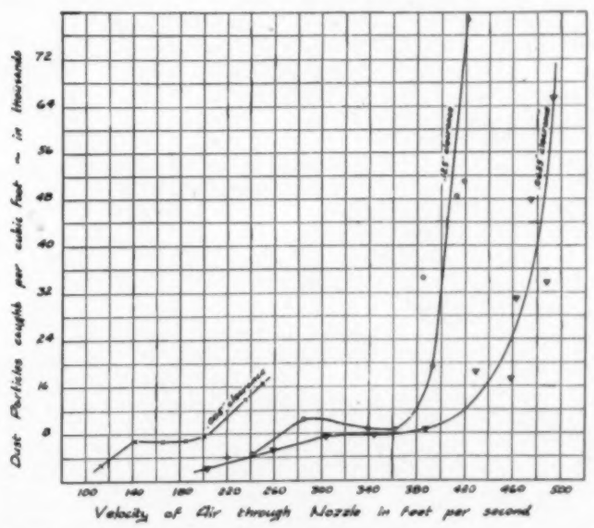


FIG. 8. EFFECT OF AIR VELOCITIES ON DUST COUNT FOR NOZZLE CLEARANCES

vals between the individual samples of a series were made as short as possible in order to eliminate variations due to changes in the natural dust content of the air. The velocities used for the different series were from 300 ft. per second to 400 ft. per second. The results

TABLE 5

Sample No.	Hill Counter No. 1		Hill Counter No. 2		Hill Counter No. 3		Constant Velocity Counter	
	Dust per Cu. Ft.	Per Cent Variation from Average	Dust per Cu. Ft.	Per Cent Variation from Average	Dust per Cu. Ft.	Per Cent Variation from Average	Dust per Cu. Ft.	Per Cent Variation from Average
1	15,780	− 6.2	14,150	−12.7	18,080	− 5.3	18,220	
2	13,590	−19.2	20,950	+36.0	13,590	−28.8	19,490	+6.9
3	17,500	+ 4.0	17,500	+ 7.2	14,040	−26.5	17,280	−5.2
4	16,340	− 2.9	15,780	− 3.0	13,590	−28.8	18,280	+0.3
5	18,420	+ 9.5	14,400	−11.2	28,800	+50.8	18,140	−0.4
6	19,320	+14.9	14,960	− 7.9	26,500	+38.7	17,940	−1.5
Average	16,820		16,290		19,100		18,225	

for a representative group of these tests are shown in Table 4. They show a maximum variation in any case of nine per cent in either direction from the average. The possibility for a variation from the average would be greater as the number of samples are increased for each set, although from the work done it would seem that six samples are sufficient for reasonable results.

As a check on the plunger pump type of dust counter and a comparison of this method with the constant velocity method, dust was sampled by three different types of Hill dust counter and also by the constant velocity method. The Hill counters used in making these tests are numbered 1, 2 and 3. Counters Nos. 1 and 2 were of the single orifice type with microscope attached. For No. 1 the orifice was in a glass plate at a distance of 0.083 in. from a fixed glass sample plate. No. 2 was of the same type excepting that the orifice was in a metal plate and the sample plate was removable. No. 3 was an older type in which the orifice and pump were separate from the microscope.

The constant velocity apparatus is the one described in Figs. 3, 4 and 5.

The results of these tests are shown in Table 5. An analysis of the results shows that the variation in count for the samples taken at a constant velocity is much less. Since the principal difference in the method used was in the control of velocity through the orifices, it would indicate that this is the factor which might be changed to improve the Hill counter.

The final conclusions reached in this investigation were:

First: That the amount of dust taken out of the air by the impingement method depends upon several variable factors. Among these factors are size and shape of nozzle, position of nozzle with reference to the collecting plate and velocity of air through nozzle.

Second: The determinations by such a method must necessarily be relative as it is impossible under any conditions to take all dust out of the air and count the same.

Third: The size of dust particles in the air varies through a wide range, and it is evident that some minimum size must be selected below which it is not necessary to count the particles. This lower limit may be set with reference to the quality of the air desired.

Fourth: By holding the conditions constant under which the samples are taken, results may be obtained with the impingement type of counter which are reasonably consistent.

Fifth: There is nothing gained in accuracy by placing nozzles in series.

Time Lag as a Factor in Heating Engineering Practice

By James Govan[1], Toronto, Canada
NON-MEMBER

THE chief purpose of this paper is to suggest an alternative definition of *Resistance* as used in determining heat transmission coefficients.

Where the definition of Resistance as used is as follows:

The Resistance, *R*, of material arranged in layers each of uniform thickness between parallel faces is equal to the number of deg. Fahr. difference in temperature of the faces required to maintain a rate of heat flow of one B. t. u. per hour per square foot of area; the suggested alternative definition of Resistance would be:

The Resistance, *R*, of material arranged in layers each of uniform thickness between parallel faces is equal to the number of hours required for one B. t. u. to flow through one square foot of area, when there is a differ-

[1] Member Royal Architectural Institute of Canada. For presentation at the Semi-Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Bigwin Inn, Lake-of-Bays, Ontario, Canada, June, 1929.

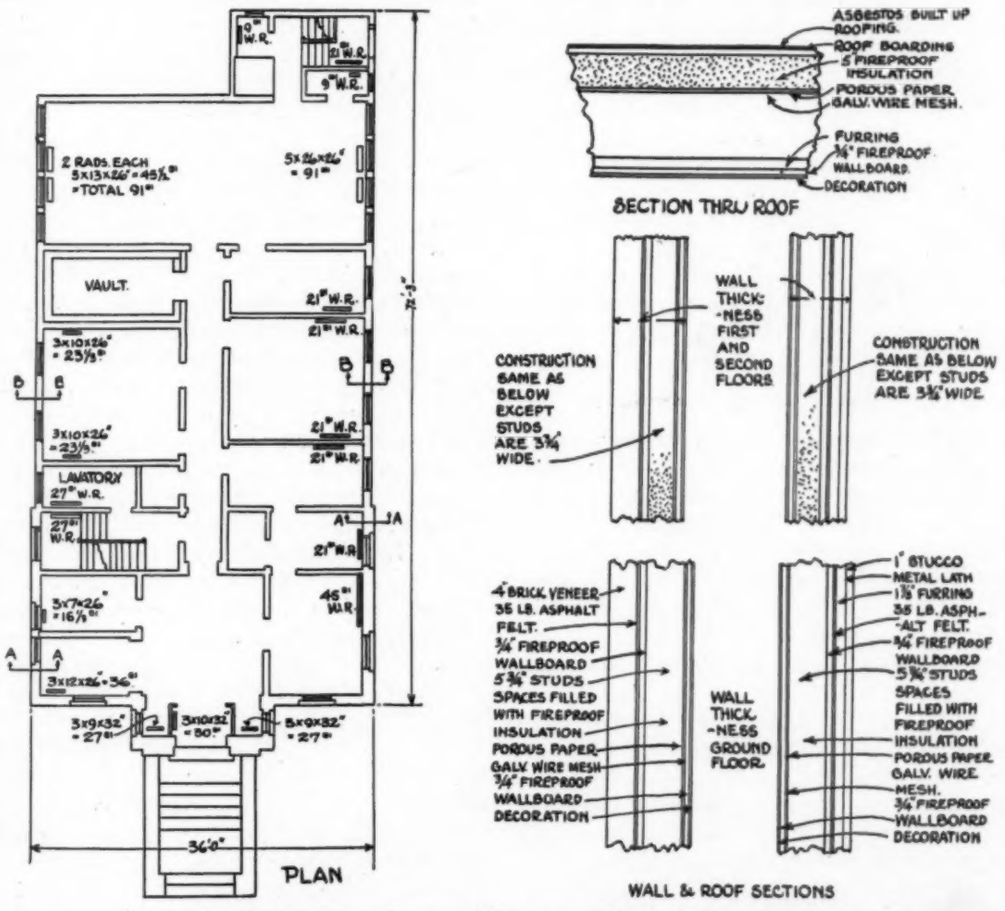


FIG. 1.—GROUND FLOOR PLAN, AND DETAILS OF WALL AND ROOF SECTIONS

FIG. 2.—SMALL OFFICE BUILDING, WHOSE GROUND FLOOR PLAN IS SHOWN IN FIG. 1

ence of one deg. fahr. in temperature between the faces.

Similarly, Surface Resistance would be expressed in Hours for one B. t. u. to flow through one square foot of surface, when there is one deg. fahr. difference between a fluid medium and the surface with which the medium is in contact.

With the adoption of the suggested alternative definition of Resistance, there would follow a clearer perception of walls and roofs of buildings as blankets delaying, more or less effectively, the passage of heat through them, in addition to performing their more generally understood functions as protectors against wind, rain and snow, and providing privacy, carrying loads, etc.

The secondary purpose of the paper is to call attention to the effect of the retention of heat in buildings having very greatly increased resistance to heat flow, when the calculations to determine the size of the heating plant are based on the recommendations of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS GUIDE.

The thought prompting the presentation of the paper by an architect is the need for a better understanding between engineer and architect of the mutual problems affecting not only themselves, but, more so, their clients.

Reasons for Suggested Alternative Definition:

The mere fact that you have been so gracious as to invite an architect to present such a paper as this, indicates that some, at least, of the members of your Society are willing to study your work from the outsider's angle, and that all of them don't feel that you have to make your engineering data more difficult to understand in order to preserve for your profession the privileges of heating engineering practice.

If by any chance your ranks are divided, like those of the medical profession, into two groups, one anxious to reduce the cost of service to the lowest possible point, and the other resisting to the utmost any departure from the recognized and approved professional position, let me assure the latter that the more the public (and that includes architects) clearly understand the elementary factors that govern your work, the more they will be willing to allow themselves to be guided by your members and less by unscientific individuals, who happen to know where to buy, on credit, boilers, pipe and fittings.

If it be conceded then that there would be an advantage to the engineer, to the architect and to the public if there was a closer understanding between the engineer and architect, as to the service that can only be rendered by a competent engineer, the first necessity, in the creation of such an understanding, is that both parties should use language that both can understand.

Now architects may be uneducated or pig-headed or lazy or conceited or they may be all four at once, but the fact remains that very few of them can or will take the trouble to understand even the definitions of the terms that you use in your studies of their buildings, to determine whether their walls, roofs and openings will leak heat like sieves or give their clients reasonable service for money expended.

That this difficulty besets others than architects can be clearly demonstrated, if one tries to address a non-technical audience on the subject of heat losses from buildings, because, under these circumstances, it becomes at once apparent that any attempt to use the language of your official GUIDE produces such confusion of thought, as is evidenced every day in the advertising of the various insulating materials now spread before us, not only in our technical journals but also in the daily press and even more so in the popular magazines.

The modification of your accepted definition of Resistance, that I am suggesting for your consideration, is one that I was prompted to make several years ago to a small group of business associates, and its reception then, and since at a meeting of the Better Business Bureau in New York over a year ago and at a meeting of the Toronto Branch of the *American Society of Mechanical Engineers,* indicates that it had something of novelty and sufficient merit to provoke favorable comment.

Whether your members may have considered the idea before I know not, but The GUIDE 1929 continues to use the accepted definition, so I presume that so far as your own needs are concerned the official position is that there is no occasion for change.

As in the case of the doctor's Latin prescription, this attitude may serve a useful purpose between the professional engineer, who detects the defects in a building and prescribes accordingly, and his contractor colleague, who fills the prescription for the architect and his client

to swallow. But when the broadcasting of advice to the public is undertaken, Latin no longer serves the doctor in public health work and the simpler the language used by the engineer the more effective will his propaganda be.

However, apart from all considerations as to whether your technical language needs to be understood by anybody outside the engineering profession, sufficient evidence is accumulating steadily to prove that the time factor, or the time lag, must receive more consideration in studying the heating problem in certain types of jobs that are increasing in number month by month.

Before dealing with specific cases, let us imagine we are present at one of the preliminary meetings between a client and his architect and consulting engineer.

The architect describes the kind of walls he proposes to use in the building; the client, who has been reading some insulation advertisements, asks if that will be an insulated wall; the engineer replies that the transmission coefficient will be 0.278 B.t.u. per hour.

The architect looks wise and is relieved when the client says, "What the 'Sam Hill' does that mean?"

Engineer: "That means that 0.278 British Thermal Units will flow through a square foot of wall when there is one degree fahr. difference in temperature between the two sides."

Client: "Oh! is that so, well I think we should put something back of that wall to give us an air space."

Architect: "Well, we could put some 2 in. hollow tile at the back and plaster it, what would that do?"

Engineer: "That would give us 0.210 B.t.u."

Client: "Could we get anything better than that?"

Architect: "Oh yes! we could put on some furring and then plaster on ½ in. insulating board."

Engineer: "That would give us 0.147 B.t.u."

Client: "Can we do any better than that?"

Engineer: "Well, if we used a good thick insulation, say 2 in. thick, we would get 0.095 B.t.u. and by using even thicker insulation we could go down as low as 0.05 B.t.u."

Client: "What do you think of it, Mr. Architect?"

Architect: "Oh, I don't know, that 0.210 looks like a pretty fair reduction to me and I've used that kind of wall before, so I guess we had better let it go at that."

Client: "Well, whatever you say, boys, you know better than I do."

Suppose the Engineer had told them that the difference between these five walls was that number one would pass one B.t.u. per square foot, when there was a difference in temperature inside to outside of about 3.6 deg. fahr., number two the same amount of heat, when there was 4.76 deg. fahr., number three 6.8 deg. fahr., number four 10.52 deg. fahr., and number five 20 deg. fahr., would either the Architect or the client have been much wiser?

But if the engineer had told them that, granted that the same temperature was maintained in the building, the amount of heat that would be wasted through the first wall in about 3½ hours, would take 4¾ hours to get through the second wall, more than 6¾ hours through the third, 10½ hours through the fourth, and 20 hours through the wall with the extra thick insulation, would the comparison have been more vivid and would there have been more study given to the economics of the whole question?

These, of course, are hourly differences for one degree difference on the two sides of the wall. For parts of Canada having a mean temperature difference of 35 deg. fahr. between the inside of an average occupied building and the outside, during a heating season of 210 days, these 5 Resistances could be expressed as 6.17 minutes, 8.16, 11.66, 18, and 34.28 minutes respectively.

But, inasmuch as the average person does not think of fuel in terms of a single B.t.u., the comparison might just as well be made in hours for enough B.t.u.'s to equal about 1 pound of coal—say, 12,000—and for an area of 100 sq. ft. of wall instead of one square foot.

Then the figures would be 12.34 hours, 16.32, 23.32, 36, and 68.56 hours respectively, and thus we get a comparison based on values that mean something to any person of average intelligence.

Even with that explanation, our clients would probably thank us more to tell them that these differences, under the climatic conditions described, mean a difference each season as between walls numbers one and five of approximately 2¾ tons of coal for each 1,000 sq. ft. of wall built.

While it is true that not many heated buildings, having a wall Resistance of 20 hours, have so far been built, several jobs have come under my own observation having that amount of resistance in roofs, and I have had personal experience with several jobs having both wall and roof resistance of 15 hours. Such a resistance would give a saving of about 2½ tons of coal per 1,000 sq. ft. of wall built as compared with wall number one under the conditions outlined.

Changing the understanding of Resistance to mean time instead of degrees difference in temperature does, I am satisfied, create a much more definite mental picture for a man, who can imagine himself going down to the furnace and putting a match to so many dollars worth of fuel. He can easily be made to realize that with a certain type of construction his dollar's worth will last him, say, from 4 to 5 hours, and 15 or 20 hours with a different type.

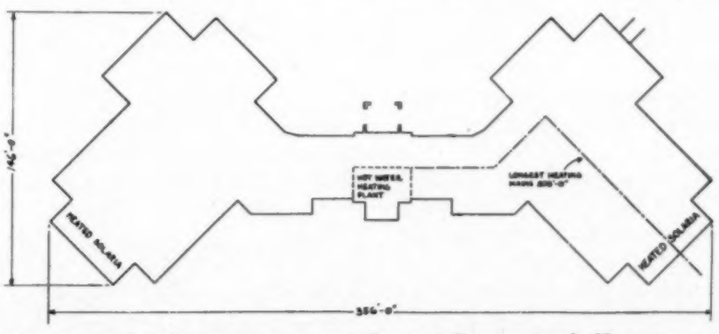


FIG. 3.—GROUND FLOOR PLAN OF THE ONTARIO GOVERNMENT'S HOSPITAL AT ORILLIA

The Effect of Heat Retention in Practice:

So much then, for clearing up the misconceptions that arise through the use of such terms as conductivity, coefficients of transmission, heat head or temperature difference, etc., etc., except when you are actually working at your desk or table or are gathered together at meetings of your society, the next point to be considered is what change, if any, does or will such high resistance make in heating engineering practice?

Far be it from me to attempt to answer such a question.

Your attention, however, is drawn to certain conditions that have been noted in some buildings and to the following considerations.

Your GUIDE recommends that the outside temperature to be assumed in the design of any heating system must not be more than 15 deg. fahr. above the lowest recorded temperature as reported by the U. S. Weather Bureau during the preceding 10 years for the locality in which the heating system is to be installed.

The GUIDE further stipulates that as the lowest temperatures recorded are usually of short duration, these conditions can readily be taken care of by the heat capacity of the building itself.

These recommendations must have been based on actual heating experience in buildings that have proved satisfactory to occupants over a considerable number of years.

Inasmuch, therefore, as up till very recently, there were few heated buildings that had anything more than a layer of very thin insulation, the Resistance of the walls and roof of the average building would not probably exceed 5 hours.

If that resistance has proved sufficient to take care of the assumptions your GUIDE recommends, does it not follow that when the resistance is doubled and in some cases quadrupled, your assumptions should be modified?

From personal observation of a number of jobs during the past few years, I think it is fair to say that many members of your Society having good professional reputations do not assume outside temperatures 15 deg. fahr. above the lowest recorded for a 10 year period, but prefer a more conservative figure from 5 to 10 degrees lower than the 15 deg. margin would give.

Some of your Toronto members, for instance, have assured me that, theoretically, they could figure their work down to zero, but in actual practice they find that jobs so estimated are liable to give trouble several days in each season.

Other so-called heating engineers, with no professional reputation to lose, are not so reluctant to take a chance and do figure down to about zero. When they are dealing with jobs having wall and roof resistances of 5 hours, or even less, the results are generally bad, whenever the outside temperature drops very much below zero.

My contention is that the development of construction having resistances of 10, 15 or 20 hours makes it possible for the most conservative and reliable engineer to assume that the heat retaining property of such buildings will take care of all possible contingencies below the point generally figured by his competitors. On the other hand, the irresponsible cut price individual—in Toronto for instance—would have difficulty in persuading his customers to let him figure to about 10 deg. above zero, because temperatures of 14 to 16 deg. below zero are recorded—unofficially—quite frequently in Toronto and neighborhood.

It is unfortunate that, at the time of writing this paper, definite scientific data on support of my contention are not available in the form you are used to in the presentation of papers for your meetings.

I do submit, however, the ground floor plan (Fig. 1) and photograph (Fig. 2) of a small office building in which I have had an opportunity of personally noting, pretty carefully, the operating results during the past winter.

This building stands exposed on all four sides, has no storm sash or storm doors, single thickness Vitaglass in windows, weather stripped. The sashes are of the superior type each sliding vertically, while it is also possible to pivot them from the bottom so that they open inwards at the top and thus provide ventilation without direct draft on anyone sitting close by a window.

I mention this detail because it has a very decided bearing on the heating results obtained in the building; first, because the type of window encourages opening for ventilation, and second, because, although I have described it as weatherstripped, it has features that make it impossible to compare it with an ordinary double hung window weather-stripped.

The ground floor wall resistance was figured as 18.86 hours, transmission coefficient 0.053; the walls of two upper stories 14 hours, coefficient 0.071; roof 15.15 hours, coefficient 0.066.

Heating was calculated to zero and 160 B.t.u.'s were assumed per square foot of radiation.

A gravity magazine feed type boiler is used and the fuel buckwheat anthracite. The boiler is not yet covered and mains in basement have only been covered since about the end of February; in the latter case the resistance provided is at least twice that usually given in ordinary commercial thickness coverings.

The results so far observed are that on the coldest day noted during the winter, when 22 deg. fahr. below zero was recorded in the morning, the temperature of the water at the boiler about 10 A. M. was 124 deg. fahr. and during the forenoon a tour of the building showed that a large number of the windows were open at the midrail for ventilation purposes.

In one room on the top floor, where I spent most of the day, the radiator was shut off entirely about 10 A. M. and was not opened again until 6 P. M., and during that time the window was slightly open at the center.

The caretaker advises me that since he has assumed control of the plant, the highest he has noted the temperature at the boiler was 135 deg. fahr. and that rise has only occurred when wind conditions cause excessive draft in the chimney and he cannot keep the temperature of the water at the boiler lower, as would be desirable.

My own examinations of the thermometer at the boiler have shown fluctuations from 98 fahr. to 124 fahr. and the building as completed is comfortable throughout every room.

Coal consumption for December, January, February and March averaged approximately 1 ton buckwheat per week.

As showing how the results in this building compare with what is evidently accepted practice, the temperature of water, recommended by the manufacturers of the pressure control tanks used, in relation to outside temperature is as follows:

Outside Temperature	*Boiler Temperature*
60 degrees above	120 degrees
50 degrees above	130 degrees
40 degrees above	145 degrees
30 degrees above	160 degrees
20 degrees above	170 degrees
10 degrees above	180 degrees
0 Zero	190 degrees
10 degrees below	200 degrees
20 degrees below	210 degrees
30 degrees below	225 degrees

Even although they add that these temperatures will vary according to the condition or construction of the building, it is obvious that the departure from these figures in actual experience need not have been so great if less radiation had been installed, which means that the job could have been figured for an outside temperature quite a bit above zero, or, in other words, considerably more than 15 degrees higher than the lowest recorded temperature for a 10 year period.

In case there should be any question as to whether the method of figuring the radiation for this building showed any departure from the recommendations of your Society, the assumptions and calculations as actually used to determine the radiation for different rooms were submitted to one of the members of your Council.

Without checking all the calculations, but after examining my figures in some detail, he has expressed the opinion that the amount of radiation is not overestimated, and is in accordance with the rules laid down for your members in the 1929 GUIDE.

Air infiltration was not figured by the crack method, because, although the sashes are weather-stripped, the particular type of sash and frame construction used is so different from any type on which I could find any record of tests in published documents.

With windows having two vertical cracks at the side of each sash instead of one, and only one of them weather-stripped, I did not feel that test figures could be made to apply. Estimates of air change were therefore made, and the changes assumed strictly adhere to Table 14, Page 49, of THE GUIDE 1929.

While I cannot give the same definite information about the Orillia Hospital Job, I can vouch for the fact that the best data, available at the time of construction, were used, and the results are, as you will note, very similar to what the office building gives.

Forced Hot Water Heating:

For forced hot water heating, Page 117 of THE GUIDE 1929 shows a chart of maximum water temperatures for different outdoor temperatures.

Contrast these figures, showing 130 deg. water at 50 deg. outside, increasing to 230 deg. water at 20 deg. below zero outside, with the actual experience on a forced hot water job at the Ontario Government's Hospital, Orillia.

There, as the result of wall and roof resistances of at least 12 and 20 hours respectively, I am advised by the operating engineer that, at about 30 deg. below zero outside, the maximum temperature of the water at the heater has not exceeded 150 deg. and that a maximum of 140 deg. will take care of the ordinary very cold dips that have been experienced during the four years of the operation of this part of their heating system.

Notwithstanding the wide-spreading area of this one-story hospital building, it has been found that for most weather conditions the water can be circulated by gravity with a temperature drop of about 20 degrees between the flow and return at the heater, and that the pumps are only required in very extreme low dips, when the flow and return temperature difference only varies from 4 to 8 deg.

As is the case with the office building previously referred to, the operator's chief difficulty is to keep the temperature of the building down with the plant as installed, even although at the hospital many hundreds of feet of radiation, originally included in the installation, have been removed and utilized in other buildings. The tendency to open the windows in cold weather noted at the office building, is also observable at Orillia.

Fig. 3 gives an idea of the area covered by the Orillia building.

FIG. 4.—HOUSES NOS. 1 AND 2

Going further north to the still colder climate at the Paymaster Mine at South Porcupine, Ontario, one can find additional evidence of the need for revising heating assumptions as construction methods change.

The developments there are very fully dealt with in three articles in the *Engineering and Mining Journal* (New York) February 16, March 2 and March 16, 1929, *Economical and Efficient Housing in Hot and Cold Climates* by H. E. Clement and the writer.

Residence Heating:

Fig. 4 shows two houses marked 1 and 2 and the following data are supplied by one of the largest firms of general contractors in northern Canada (dated April 6, 1929).

House No. 1: 26 ft. x 33 ft.; 12,500 cu. ft. contents in house proper and 5,900 cu. ft. in basement; coal consumed since last fall 7 tons; house heated evenly, having a uniform temperature of 70 deg. or slightly over at all times; 350 sq. ft. hot water radiation; boiler is a jacketed, hot water, domestic heater having a grate 15 in. in diameter, but not rated in radiator capacity

as it is not ordinarily used for heating buildings; temperature of water 140 deg. with outside temperature from 25 deg. to 35 deg. below zero; average temperature of water for three cold winter months 130 deg. Occupant of this house is an engineer and is the master mechanic for the construction company. He reports that as the extreme cold weather only lasts from 24 to 48 hours, he could not see any very marked difference in the firing to keep the house at the same temperature during extreme cold weather. Resistance of walls and roof of house No. 1, approximately from 12 to 14 hours.

House No. 2: 25 ft. x 29 ft., much less cubic contents than house No. 1; has 450 sq. ft. hot water radiation, average temperature water during three severe winter months 160 deg.; house not nearly so warm or so evenly heated and consumes more coal. House No. 2 was built by same construction company and was of much better construction than ordinary frame buildings as the sheathing outside of studs is double with felt between; studs sheathed with lumber inside, then felt and lath and plaster; sunroom in House No. 2 not heated, whereas in No. 1 it is built in with house and heated.

Skyscraper Possibilities:

Up to the present the results I have described have not been economically possible in skyscraper construction, but I am satisfied that within the next few years materials will be developed that will make possible wall and roof resistances of 15 to 20 hours.

The greatest stumbling block to such progress is the difficulty in getting the building by-laws in our large cities changed to allow engineers and architects to take advantage of the results of modern research work.

The demand for increased height and consequently reduced weight will compel the use of materials having very much greater resistance to heat flow than those now commonly used.

Such materials are available now and all that is needed is to adapt them to skyscraper requirements.

I have the figures for a recently erected 16-story building in Toronto before me, and I note that the resistance of the wall was figured as 3 1/3 hours and that nearly 5,000 sq. ft. of radiation was required for wall losses.

With this resistance increased to 20 hours, as will soon be possible, 800 sq. ft. of radiation would take care of the wall losses, a reduction of 4,200 sq. ft.

As the total radiation for the building was 10,000 sq. ft., the saving would represent at least 40 per cent and as it would not be necessary to figure down to as low an outside temperature the saving would probably be even more than 40 per cent.

In dollars and cents at present prices in Toronto, it would amount to at least $7,000.00 and for this particular building that represents about 15 cents per sq. ft. of exterior wall.

The new construction materials to give such results will not be added to the existing types, but will take the place of some of them. Even with present developments known to research organizations, an allowance of 15 cents per sq. ft. of wall or roof would go a long way towards making up any difference between the cost of what we now do and what we will do in the near future.

Intermittent Heating:

In buildings where the heating problem is complicated because of intermittent use, such as churches, club-rooms, etc., a substantial increase in resistance to heat loss offers a much more economical solution of the problem than the provision of excess stand-by heating equipment.

My attention has been drawn to several cases, where the amount of heating plant installed for this purpose represents not only considerable capital outlay, but also a very wasteful annual expenditure for maintenance and operation.

In this connection, it should be noted that while the work already done shows that high resistance will permit large reductions in the amount of radiation, care should be taken in cutting down the sizes of heating mains and boilers. Free and rapid circulation is essential.

These jobs I have had to do with personally have been successful, I believe, because my associates have given special attention to this feature of the work.

Use of Gas and Electricity for Heating:

Your members know more than I do about the future possibilities in the use of gas, electricity, oil, etc., for heating all kinds of structures, but I think you will agree that their fullest development will only be possible when we, as architects, provide you, as engineers, with wall and roof resistance sufficient to bring the cost to the consumer within the reach of a much larger clientele than will now consider such methods. However, the demand for labor saving equipment is spreading and your practice along such lines will undoubtedly be influenced by your co-operation in educating the public, and educating the public can only be done by using language it can understand.

Conclusion:

I may not have submitted enough technical data to show that the points raised in this paper are of any serious interest to practising engineers.

I submit, however, that no Society, professional or otherwise, can achieve its greatest end, namely, service to its members, when these members are dependent on the support of all the people, unless it makes its work known to the greatest possible number of people.

This paper, then, is a plea for a wider diffusion of knowledge of heating possibilities by using language that would make such diffusion possible.

Five Suggested Methods of Appraising Insulations

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MEMBER

THE insulation industry is growing rapidly. New materials are being developed constantly, and the insulation idea is becoming more and more popular through intensive advertising and promotion. Unfortunately, however, the public in general does not have sufficient knowledge of the meaning of the word insulation to be able to differentiate between insulating materials and those not entitled to this classification. The result is that many unwarranted claims are being made by concerns who are endeavoring to capitalize on the promotional work being done at the expense of the ignorance of the public of the subject of insulation.

As an example, exceptional insulating qualities are claimed for a new building paper, but it is a fact well known to heating engineers that the heat resistance of building paper is so small that it may be safely neglected in heat transmission computations. Building paper is, of course, intended primarily to reduce air infiltration through a wall.

An imitation marble about ⅛ in. thick is claimed to have high resistance to the passage of heat and *cold*. It is contended that a certain plaster board used in place of ordinary materials will result in a substantial saving in fuel and reduction in the amount of radiation required for a building. It is also stated that this product is more impervious to infiltration than other materials, although recent tests indicate that infiltration through almost any plastered wall is a negligible quantity.

A corrugated paper ⅛ in. thick is promoted for insulation purposes, and it is claimed that thickness is not essential with this product. There are also other materials for which extravagant claims are made which, although having relatively low conductivities, are not installed in sufficient thicknesses to result in an appreciable reduction in the heat transmission.

In addition to the many unwarranted claims being made, there is an endless amount of controversy over small differences in conductivities of insulations. Such differences are usually within the error of testing, and are insignificant when compared on the basis of over-all transmissions. It is certain that they are of far less consequence than other variables entering into heating calculations. This chaotic state of affairs suggests the need for a means of grouping or classifying insulations, and for rating them.

The following suggested methods are designed to serve this purpose, but should not be construed as standards, as they are merely offered for preliminary consideration to encourage further thought on the subject.

TABLE 1—SUGGESTED CLASSIFICATION OF INSULATIONS ACCORDING TO CONDUCTIVITIES

RATING	CONDUCTIVITY RANGE (B. t. u. per hr. per sq. ft. per 1 deg. fahr. per in.)	TYPES OF INSULATION		
		RIGID	FLEXIBLE	FILLS
Class A	0.30 or under	7 lb. Corkboard 10.6 lb. Corkboard Torfoleum	Balsam Wool Cabots Quilt Dry Zero Hairinsul Hair Felt Keystone Hair Linofelt Themofelt (Hair and asbestos)	Rock Wool Sprayo-flake
Class B	0.301 to 0.35	7.3 lb. Balsa Wood Celotex 14 lb. Corkboard Inso Board Insulite Masonite Maftex	Fibrofelt Flaxlinum	Granulated Cork 18 lb. Thermofill
Class C	0.351 to 0.40	8.8 lb. Balsa Wood Homasote Lith Rock Cork Thermosote	Themofelt (Jute and asbestos)	
Class D	0.401 to 0.50			12 lb. Insulex 12 lb. Pyrocell 24 lb. Thermofill
Class E	0.501 to 0.60	20 lb. Balsa Wood Magnesia		18 lb. Insulex 18 lb. Pyrocell 26 lb. Thermofill 34 lb. Thermofill
Class F	Above 0.60	Not Classed as Insulations.		

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For presentation at the Semi-Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Bigwin Inn, Lake-of-Bays, Ontario, Canada, June 1929.

Grouping of Insulations by Conductivities

The first suggested method of classifying insulations is to group them according to their conductivities as shown in Table 1. By this method, all insulations having conductivities of 0.30 B.t.u. per hour, per square foot per degree fahr., per inch of thickness or below, would be designated as Class *A* materials; those between 0.301 and 0.35, Class *B* materials; 0.351 to 0.40, Class *C;* 0.401 to 0.50, Class *D*; and 0.501 to 0.60, Class *E*. Materials having conductivities higher than 0.60 would not be classified as insulations. The classifications given in Table 1 are in most cases based on conductivities published in Table 5, Chapter 1, of the A. S. H. & V. E. *Guide* 1929, using U. S. Bureau of Standards values where tests by this authority have been made.

It will be noted that the materials in Table 1 are grouped according to types of insulation, namely, rigid insulations, flexible insulations and fills. Cork board and the board forms of insulation are classified as rigid materials; the so-called felts, quilts and soft materials are designated as flexible insulations, and the powdered, flaked and aerated materials usually confined between the studding, joints, rafters or furring strips are designated as fills. Thus, pure cork board having a density of 7.0 lb. per cubic foot would be a Class *A* rigid insulation, and hair felt a Class *A* flexible insulation. A cellular gypsum fill having a density of 18 lb. per cubic foot, and a conductivity of 0.59 per inch of thickness, would be a Class *D* fill.

One of the fallacies of the foregoing system is that it does not afford a true comparison between materials of different types of the same or different conductivities installed in different thicknesses. Neither is the manner of installation taken into consideration by this method. A Class *C* fill, if installed between the studding in a thickness of 3⅝ in. may reduce the heat transmission of a certain wall to a greater extent than a Class *B* rigid insulation, or a Class *A* flexible insulation. Similarly, a Class *B flexible* may be more effective than a Class *A rigid* due to the manner of installation.

TABLE 2—CLASSIFICATION OF INSULATIONS ACCORDING TO HEAT RESISTANCE OF THICKNESS INSTALLED

RATING	HEAT RESISTANCE ADDED
Class A	10.01 or more
Class B	9.01 to 10.00
Class C	8.01 to 9.00
Class D	7.01 to 8.00
Class E	6.01 to 7.00
Class F	5.01 to 6.00
Class G	4.01 to 5.00
Class H	3.01 to 4.00
Class I	2.01 to 3.00
Class J	1.01 to 2.00

Comparison by Resistance Method

The second proposed method which has no bearing on the first one, would classify insulations according to the total heat resistance they add to a given type of construction, thus giving consideration to the conductivity as well as the thickness installed. Suggested classifications according to this method are given in Table 2. A 1 in. thickness of a rigid insulation having a conductivity of 0.33 B.t.u. per hour per square foot per degree fahr. per inch of thickness, would add a resistance of $\frac{1.0}{0.33}$ or 3.03 and would therefore be a Class *H* insulation. A 1 in. thickness of a flexible insulation having a conductivity of 0.27 B.t.u. per hour per square foot per degree fahr. per inch of thickness, would add a resistance of $\frac{1.0}{0.27}$ or 3.70, and would therefore be given the same classification in this case. If a fill having a conductivity of 0.50 B.t.u. per hour per square foot per degree fahr. per inch of thickness, is installed between 2x4 in. studding, the actual heat resistance of the thickness installed would be $\frac{3.625^2}{0.50}$ or 7.30, and this material would then be given the Class D rating according to Table 2. The chart (Fig. 1), which is based on the ratings given in Table 2, may be used for determining the resistance and classification of any insulation according to the conductivity and thickness installed.

Fills are usually installed so that an air space is entirely filled, thereby canceling the insulating effect of the air space, which for purposes of comparison, should be deducted from the resistance of the installed thickness of the insulation. On the other hand, rigid and flexible insulations may be applied so as to create one or more additional air spaces, or a rigid insulation may be used in place of other building materials. To be strictly correct, therefore, any comparison on the basis of resistances should also take these facts into consideration.

Percentage Reduction in Heat Transmission

The resistance method of comparison or classification may be objected to on the grounds that such a method is an indirect one and does not indicate the true relationship between two materials as installed from the standpoint of effectiveness.

Resistances afford an easy method of comparison because they are additive, but unfortunately they do not tell the complete story. Neither are conductances (the reciprocals of resistances) of the actual thicknesses installed (Tables 3 and 4) correct indices of the relative merits of insulations, even considering air spaces and other factors. Hence, it seems logical that exact comparisons should be made between over-all transmissions of insulated and uninsulated constructions.

The third suggested method of classification therefore, involves the principle that the degree of insulation obtained approaches 100 per cent as the heat transmission coefficient approaches zero. In other words, a material installed in a sufficient thickness

[2] 3.625 represents the actual width in inches of 2 x 4 in. studding.

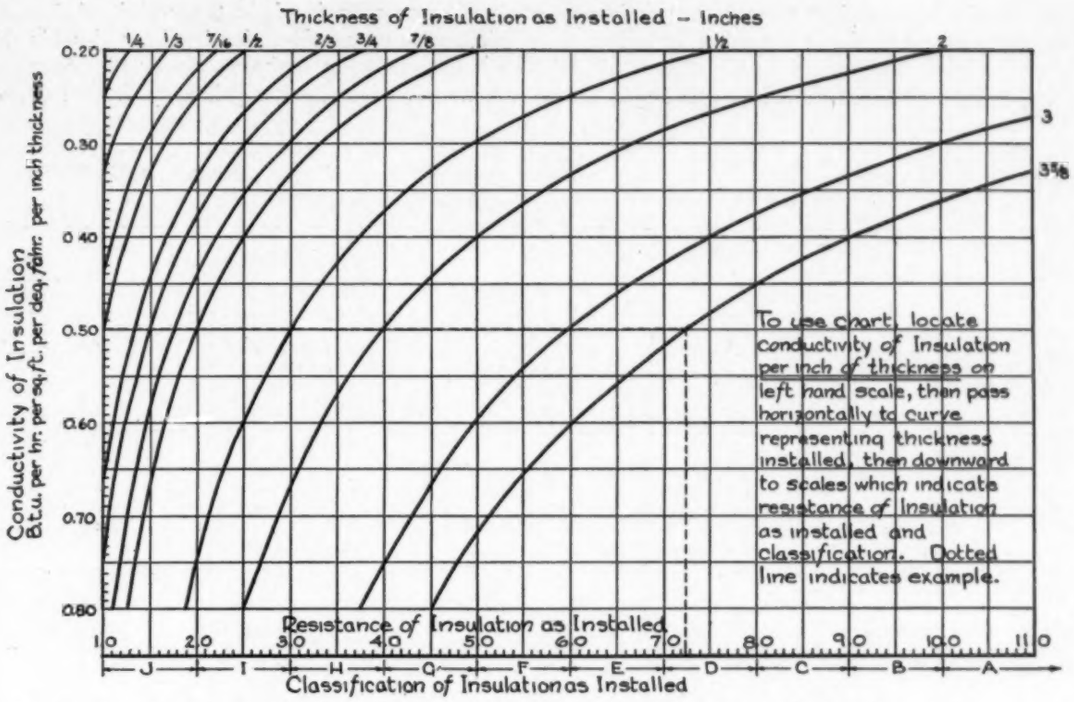
Thickness of Insulation as Installed – Inches
1/4 1/3 7/16 1/2 2/3 3/4 7/8 1 1½ 2 3 3⅝
Conductivity of Insulation B.t.u. per hr. per sq. ft. per deg. fahr. per inch thickness
0.20 0.30 0.40 0.50 0.60 0.70 0.80
To use chart, locate conductivity of insulation per inch of thickness on left hand scale, then pass horizontally to curve representing thickness installed, then downward to scales which indicate resistance of insulation as installed and classification. Dotted line indicates example.
Resistance of Insulation as Installed
1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0
J I H G F E D C B A
Classification of Insulation as Installed

FIG. 1. CHART FOR DETERMINING CLASSIFICATION OF INSULATIONS ON BASIS OF HEAT RESISTANCE INSTALLED.

or having a sufficiently low conductance for the thickness installed to reduce the heat transmission to a value approaching zero, would have an insulating value approaching 100 per cent. This relationship is expressed by the formula:

$$E = 100 \left(\frac{U_o - U_1}{U_o}\right) \text{ per cent.}$$

where—

E=Efficiency of the thickness of insulation installed or the percentage reduction in heat transmission.[3]

U_o=Coefficient of transmission of the uninsulated construction;

U_1=Coefficient of transmission of the insulated construction.

Theoretically, a *perfect* insulation would reduce the heat transmission through a wall or roof to zero, and would therefore be classified as a 100 per cent insulation. The degree to which a 100 per cent insulated construction is obtained by any given thickness of a material of a certain conductivity would govern the classification of the material. Suppose, for example, the uninsulated construction were a frame wall, consisting of wood siding, building paper, wood sheathing, studding, wood lath and plaster, having a coefficient of transmission of 0.227 B.t.u. per hour per square foot per deg. fahr. (Table 8-A, p. 33, Chapter I, the A. S. H. & V. E. GUIDE 1929). If the sheathing, building paper and lath of this construction are replaced with two ½ in. thicknesses of a rigid insulation, the heat transmission will be reduced to 0.157 B.t.u. per hour per square foot per deg. fahr., and the value of E for this material in this case would be—

$$100 \times \frac{0.227 - 0.157}{0.227} = 31 \text{ per cent.}^3$$

If, instead of the rigid insulation being used in place of the sheathing and lath, a 1 in. thickness of a flexible insulation, having a conductivity of 0.27 B.t.u. per hour, per square foot per deg. fahr. per inch of thickness, is installed between the studding, the coefficient of heat transmission will be 0.104 B.t.u. per hour, per square foot per deg. fahr. per inch of thickness, and E for the thickness of this insulation installed, for the manner of installation and for the construction, will be—

$$100 \times \frac{0.227 - 0.104}{0.227} = 54.3 \text{ per cent.}^3$$

If the spaces between studding are filled with a cellular gypsum fill, the heat transmission coefficient will be 0.110 B.t.u. per hour per square foot per deg. fahr., and the efficiency of the insulation or the value of E in this case will be—

$$100 \times \frac{(0.227 - 0.110)}{0.227} = 51.5 \text{ per cent.}^3$$

By this method insulations could be rated on a percentage basis or classified in a manner similar to that shown in Table 5.

Recent experiments conducted at the University of Illinois show that as the heat transmission coefficient of a ceiling is decreased by the addition of insulation, the temperature of the air at the ceiling is increased and the temperature above the ceiling is decreased, thus tending to offset, in a measure, the effect of the insulation. Hence, although one insulation may reduce the heat transmission through a ceiling or a roof twice as much as another, it will not be twice as effective because of

[3] The value of E is not an index of the percentage saved of the fuel or radiation required to heat a building. The percentage saved of the total heat losses obtained by insulating the walls and/or roof of a building must necessarily involve all of the heat losses, including the infiltration losses and the transmission losses through glass.

the increase in the heat head or temperature difference. Therefore, accurate comparisons involving overall transmissions of constructions should take account of this fact, the importance of which cannot be overemphasized.

Rating on Basis of Cost per Unit of Resistance

Thus far no consideration has been given in this paper to costs. Heating engineers are usually concerned with the matter of insulation primarily from the standpoint

TABLE 3.—CONDUCTANCES OF VARIOUS THICKNESSES OF INSULATIONS BASED ON TESTS CONDUCTED AT U. S. BUREAU OF STANDARDS AND COMPUTED FROM CONDUCTIVITIES PER INCH OF THICKNESS

MATERIAL	DESCRIPTION	DENSITY (lb. per cu. ft.)	MEAN TEMP. (deg. fahr.)	THICKNESS OF INSULATION—INCHES													
				1/3	3/8	7/16	1/2	2/3	3/4	7/8	1	1 1/2	1 5/8	1 3/4	2	3	3 5/8	5 5/8
Balsam Wool	Chemically treated wood fiber	2.2	90				0.54				0.27							
Cabots Quilt	Eel grass between Kraft paper	4.6	90	0.78			0.52	0.39			0.26							
Cabots Quilt	Eel grass between Kraft paper	3.4	90	0.75			0.50	0.375			0.25							
Celotex	Board form insulation made from sugar cane fiber	13.2	90			0.777	0.68			0.389	0.34	0.227		0.194	0.17	0.113		
Corkboard	Pure; no added binder	14.0	90								0.34	0.227			0.17	0.113		
Corkboard	Pure; no added binder	10.6	90								0.30	0.20			0.15	0.10		
Corkboard	Pure; no added binder	7.0	90								0.27	0.18			0.135	0.09		
Corkboard	Pure; no added binder	5.4	90								0.25	0.167			0.125	0.083		
Corkboard (Eureka)	Asphaltic binder	14.5	90								0.32	0.213			0.16	0.107		
Dry Zero	Kapok between burlap or paper	2.0	90								0.25							
Dry Zero	Kapok between burlap or paper	1.0	90								0.24							
Fibrofelt	Flax and rye fiber	13.6	90	0.96	0.853		0.64		0.426		0.32							
Flaxlinum	Flax fiber	13.0	90				0.62				0.31							
Hairinsul	(75 per cent hair) (25 per cent jute)	6.3	90				0.54		0.36		0.27							
Hairinsul	(50 per cent hair) (50 per cent jute)	6.1	90				0.52		0.347		0.26							
Hair felt	Felted Cattle Hair	13.0	90				0.52				0.26							
Hair felt	Felted Cattle Hair	11.0	90				0.52				0.26							
Insulex or Pyrocell	Cellular Gypsum	30.0	90								1.00		0.615				0.276	0.178
Insulex or Pyrocell	Cellular Gypsum	24.0	90								0.77		0.473				0.212	0.137
Insulex or Pyrocell	Cellular Gypsum	18.0	90								0.59		0.363				0.163	0.105
Insulex or Pyrocell	Cellular Gypsum	12.0	90								0.44		0.271				0.121	0.078
Insulite	Board form insulation made from wood	16.9	90				0.68				0.34							
Linofelt	Flax fibers between paper	4.9	90		0.747		0.56				0.28							
Lith	Rock wool, flax and straw pulp with binder	14.3	90								0.40	0.267			0.20	0.133		
Regranulated Cork	About 3/16 in. particles	8.1	90								0.31		0.191				0.086	0.055
Rock Cork	Rock wool block with binder	16.7	86								0.37				0.185	0.123		
Rock Wool	Fibrous material, made from rock	10.0	90								0.27		0.166				0.075	0.048
Sprayo-Flake	Shredded paper with silica binder	4.2	94				0.56		0.373	0.32	0.28	0.186			0.14	0.093		
Thermofelt	Jute and asbestos fibers, felted	10.0	90				0.74				0.37							
Thermofelt	Hair and asbestos fibers, felted	7.8	90				0.56				0.28							
Thermofill	Dry, Fluffy, Flaked Gypsum	34.0	90								0.60		0.369				0.165	0.107
Thermofill	Dry, Fluffy, Flaked Gypsum	26.0	90								0.52		0.32				0.143	0.092
Torfoleum	Peat Moss compressed into sheet form	10.2	91.5								0.29	0.193		0.166	0.145	0.097		

of the proper design and functioning of the heating system. But whether the engineer or some one else is the deciding factor in the selection of the insulation, an intelligent comparison cannot be made unless some consideration is given to costs, assuming that all materials involved are suitable for building purposes.

Table 5—Classification of Insulations on Basis of Efficiency of Insulation for Any Specific Type of Construction

Rating	E $100x(U_0—U_1)$ / U_0
Class A	90% to 100%
Class B	80% to 90%
Class C	70% to 80%
Class D	60% to 70%
Class E	50% to 60%
Class F	40% to 50%
Class G	30% to 40%
Class H	20% to 30%
Class I	10% to 20%

Neglecting all other factors but cost of insulation, thickness, and the conductivity, it is possible to obtain a comparatively simple basis for comparison, namely, the cost per unit of resistance. For example, a so-called rigid insulation, such as cork board, having a conductivity of 0.30 per inch, and costing 15c per square foot per $1\frac{1}{2}$ in. thickness, would cost $\frac{0.30\times15}{1.50}$ or 3c per square foot per unit of resistance. A $\frac{1}{2}$ in. thickness of a flexible insulation having a conductivity of 0.27 B. t. u. per hour per square foot per deg. fahr. per inch of thickness, and costing $4\frac{1}{2}$c per square foot would cost $\frac{0.27\times45}{0.50}$ or 2.43c per square foot per unit of resistance. A fill having a conductivity of 0.50 per inch and costing 16c per square foot for a thickness of $3\frac{5}{8}$ in. would cost $\frac{0.50\times16}{3.625}$ or 2.2c per square foot per unit of resistance.

A more accurate scheme for rating insulations according to the cost per unit of resistance would be on an *installed* basis, by which consideration would be given to the cost of installation, as well as the effective resistance of the insulation as applied, thus allowing for any increase or decrease in the number of air spaces in the construction, and for any materials replaced by the insulation. In many cases the cost on an "installed" basis would be comparable to the cost on the material alone

Table 4—Conductances of Various Thicknesses of Insulations Based on Tests Conducted at Armour Institute by Prof. J. C. Peebles and Computed from Conductivities Per Inch of Thickness

Material	Description	Density (lb. per cu. ft.)	Mean Temp. of Sample (deg. fahr.)	Thickness of Insulation—Inches									
				7/16	1/2	7/8	1	1 1/2	1 5/8	2	3	3 5/8	5 5/8
Celotex	Board form insulation made from sugar cane fiber	13.5	70	0.754	0.66	0.377	0.33	0.22		0.165	0.11		
Flaxlinum	Flax fiber	14.0	70		0.64		0.32						
Homasote	Wall board (5/16" thick made from paper pulp)	22.9	70				0.40						
Inso Board	Board form insulation made from wheat straw	17.0	68	0.754			0.33						
Insulite	Board form insulation made from wood pulp	16.5	70		0.68		0.34						
Keystone Hair	Hairfelt between layers of paper; 1/4" thick	11.0	75				0.25						
Lith	Rock wool, flax and straw pulp with binder	14.5	75				0.38	0.253		0.19	0.127		
Masonite	Board form insulation made from exploded wood fiber	18.0	75	0.754			0.33						
Maftex	Board form insulation made from roots of licorice	16.1	81	0.77			0.337						
Pyrocell or Insulex	Cellular Gypsum	30.0	75				0.92		0.566			0.254	0.164
Pyrocell or Insulex	Cellular Gypsum	24.0	75				0.737		0.453			0.203	0.131
Pyrocell or Insulex	Cellular Gypsum	18.0	75				0.566		0.348			0.156	0.10
Pyrocell or Insulex	Cellular Gypsum	12.0	75				0.400		0.246			0.110	0.071
Sprayo-Flake	Shredded paper with silica binder	4.5			0.50	0.286	0.25	0.167		0.125			
Thermofill	Dry, fluffy, flaked gypsum	24.0	75				0.475		0.292			0.131	0.084
Thermofill	Dry, fluffy, flaked gypsum	18.0	75				0.34		0.209			0.094	0.06
Thermosote Insulating Board	Board form insulation made from wood pulp	20.8	70	0.854			0.374						

basis, but in other cases there would undoubtedly be considerable difference.

Rating on Basis of Economic Value

One insulation may reduce the heat transmission of a certain construction to a much greater extent than another, but if the cost of the one greatly exceeds that of the other, the monetary value of the additional heat saving of the more expensive insulation may not be sufficient to justify its use; in fact, the more expensive insulation may actually be an extravagance when considered from the standpoint of return on the additional investment required.

To further illustrate this point, suppose the heat transmission of a certain uninsulated wall to be 0.25 B. t. u. per hour per square foot per degree fahr., and that one type of insulation installed in the thickness in which it is usually applied will reduce the heat transmission to 0.15 B. t. u. per hour per square foot per degree fahr., and another type will reduce it to 0.12 B. t. u. per hour per square foot per degree fahr. The fuel saving in the former case is estimated to be 1.26[4] tons of coal per 1000 sq. ft. of wall area per heating season, and would have a value of $12.60 per year based on coal at $10.00 per ton. The fuel saving in the case of the material which will reduce the heat transmission to 0.12, is estimated on the same basis to be 1.64[4] tons of coal per heating season, and would have an annual value of $16.40 if the price of coal is $10.00 per ton. If the costs of the two insulations as installed are $100.00 and $200.00 respectively, per 1000 sq. ft. of wall area, the former will result in a return on the investment of 12.6 per cent, and the latter 8.2 per cent, disregarding radiation saving, depreciation, etc. The more costly insulation in this case will save only 0.38 tons of coal per heating season more than the less expensive insulation, representing an additional monetary return of only $3.80 per heating season at an additional cost of $100.00. The return on the investment of the more expensive insulation is therefore only 3.8 per cent as compared with the first, and from the economic standpoint, would not justify the use of the more expensive insulation in this case.

Obviously, the more costly the fuel, the greater the thickness of insulation required to obtain the proper economic balance. For gas and electricity, a well insulated wall is an economic necessity. For less expensive fuels, however, more insulation than will result in an adequate annual return on the investment is a waste of money, if in determining this return all of the tangible savings accruing from the use of the insulation are taken into consideration. This does not mean that the higher the return on the investment, the better the material, because the initial thickness of any given insulation will produce a higher return on the investment than any equal subsequent thickness. In other words, each increment of insulation applied, will result in a smaller return on the investment than the preceding increment, assuming that the installed cost of each additional increment is the same. This is sometimes called the law of diminishing return. Although the return diminishes with each unit of thickness of insulation added, several thicknesses of a given form of insulation may be warranted for a certain type of construction. Of course, few forms of insulation are not susceptible of application in progressive thicknesses.

There is, however, a practical economic limit to the amount of insulation that should be installed for any given type of construction, and for any given set of conditions. Hence, in order to classify insulations according to their economic values, it would be necessary to consider the type of construction involved in each case, the conductivities, costs and thicknesses of materials, fuel and radiation savings and their monetary values, depreciation and other factors. It seems apparent, therefore, that the problem of properly classifying insulations from the economic standpoint and of determining the optimum thickness, becomes too involved to lend itself to a simple solution.

Conclusions

There is an apparent need for a method of appraising or evaluating insulations. To establish a fair and equitable basis for comparison, however, does not appear to be an easy matter. In order to encourage further thought on the subject, five plans are suggested. The first is based solely on conductivities per inch of thickness. The second is a resistance method taking into account the thickness in which the insulation is installed. The third plan is intended to rate insulations according to the extent to which they reduce the rate of heat transmission through a wall or roof, and therefore, involves the type of construction, the thickness of insulation and the manner of installation. The fourth scheme would rate insulations according to the cost per unit of resistance, either for the material alone or on an installed basis. The last plan suggests the possibility of appraising insulations according to the return on the investment.

It is evident that this subject is one which warrants further study for the purpose of rationalizing the rating and classification of insulations and eliminating quibbling over small, insignificant differences in the conductivities, which is so detrimental to the progress of the insulation industry.

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[4] Based on a heating season of 5040 hours, an average temperature difference of 30 deg. fahr., 12,000 B.t.u. per pound of coal and an overall efficiency of the heating system of 50 per cent.

Standard Adopted for Identification of Piping Systems

A SYSTEMATIC plan, for employing color and other kinds of markings for pipe lines, based on fundamental principles sponsored by the *National Safety Council* and the *American Society of Mechanical Engineers,* in cooperation with 28 organizations, has been approved by the American Engineering Standards Committee.

The need for a common method of identification of piping systems has been apparent to those concerned with this matter for many years. Standards have been in use in individual cases for some time, and in many cases have given good results. They have suffered, however, from a complete lack of uniformity, with the result that spontaneity of action in time of emergency has been lost, particularly when outside agencies such as fire departments, have been called in to assist. In general, there has been confusion in the minds of those who change employment from one plant to another, and many mills and plants, desirous of using an identification scheme, have not installed one because no generally accepted standard was available.

Papers on this subject have been presented before various technical societies from time to time since 1908, but until the recent adoption of the system under discussion by the A. E. S. C., there was no generally accepted method of designating piping systems.

Active work in the development of this system of identification of piping began in 1922 with the organization of a Sectional Committee consisting of thirty-three members representing 28 technical societies and industrial organizations. The AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS was represented by A. K. Ohmes, New York, N. Y. The personnel of this committee, which was divided into various sub-committees, was as follows:

PERSONNEL OF SECTIONAL COMMITTEE

Ross P. Anderson	New York, N. Y.	American Petroleum Institute
Harry E. Bates	Chicago, Ill.	American Gas Association
L. W. Bates	Washington, D. C.	U. S. Navy Department
Rudolph E. Bruckner	Long Island City, N.Y.	Internat'l. Acetylene Ass'n.
William L. Bunker	Los Angeles, Cal.	Society of Naval Architects and Marine Engineers
Everett J. Cole	Brooklyn, N. Y.	Nat'l. Varnish Mfrs. Ass'n.
Bureau of Construction and Repair	Washington, D. C.	U. S. Navy Department
I. J. Fairchild	Washington, D. C.	Bureau of Standards
H. E. Farrer	New York, N. Y.	Amer. Institute of Elec. Engrs.
Crosby Field	Brooklyn, N. Y.	Amer. Inst. of Chem. Engrs.
H. A. Gardner	Washington, D. C.	Nat'l. Paint, Oil & Varnish Assn.
Theo. M. Gevrenze	New York, N. Y.	Amer. Society of Mech. Engrs.
P. H. Glatfelter	Spring Grove, Pa.	Tech. Ass'n. of the Pulp and Paper Industry
Amos S. Hebble	New York, N. Y.	Society of Naval Architects and Marine Engineers
James G. Higgins	Brooklyn, N. Y.	U. S. Department of Labor
Ira G. Hoagland	New York, N. Y.	National Automatic Sprinkler Ass'n. and National Fire Protection Ass'n.
F. C. Hodgkinson	New York, N. Y.	Nat'l. Electrical Mfrs. Ass'n.
J. J. Howe	New York, N. Y.	U. S. Navy Department
Frank P. Ingalls	Brooklyn, N. Y.	Paint Mfrs. Ass'n.
LeRoy E. Kern	New York, N. Y.	Office of State Architects
S. H. Kershaw	Chicago, Ill.	National Safety Council
Willis Lawrence	New York, N. Y.	National Association of Stationary Engineers
Alexander Maxwell	New York, N. Y.	National Electric Light Ass'n.
William S. Morrison	New York, N. Y.	American Society of Mechanical Engineers
Arthur K. Ohmes	New York, N. Y.	American Society of Heating and Ventilating Engineers
M. Rea Paul	Brooklyn, N. Y.	National Lead Co., Member at Large
Ross S. Peck	New York, N. Y.	The American Society of Mechanical Engineers
A. L. Penniman	Balitmore, Md.	National Electric Light Ass'n.
Andrew A. Pfeiffer	New York, N. Y.	Pipe Covering Contractors Association
G. E. Sanford	Schenectady, N. Y.	American Society of Safety Engineers
Henry S. Smith	New York, N. Y.	Compressed Gas Manufacturers Association
William W. Smith	Kearney, N. J.	Federal Shipbuilding and Dry Dock Co., Member at Large
Frank N. Speller	Pittsburgh, Pa.	American Society of Refrigerating Engineers
R. G. Taggart	Albany, N. Y.	The State Architect
H. P. Weaver	Philadelphia, Pa.	National Safety Council
Richard A. Wolff	New York, N. Y.	Heating and Piping Contractors National Association

The ideal requirements of a standard scheme for the identification of piping systems, most of which are met by the proposed standard, are: (*a*) distinguishability, (*b*) flexibility, (*c*) inclusiveness, (*d*) simplicity, (*e*) practicality, (*f*) rationality.

Under the proposed system, all fluids are divided into five major classes which are (*1*) fire protection materials, (*2*) dangerous materials, (*3*) safe materials, (*4*) protective materials and (*5*) extra valuable materials. The piping is so colored as to designate which of the classes of fluids are being conveyed by the system. The color may be applied over the entire system, or in bands near valves, or at other prominent places. More exact designation of the fluids may be accomplished by stripes, stencilled letters, words or figures on the bands.

Although this system may not be a perfect one, the present need is for a clear, concise scheme which will quickly establish in the minds of plant employees the danger or safety of materials carried in a given pipe. Then by the use of secondary color or legend the scheme

may be expanded in a given plant or industry to permit the complete identification of the materials in the piping system.

It is the hope of the Committee that industry as a whole will adopt the proposed system, even though it is recognized that the supplementing of present systems and the adoption of a new one must of necessity be accomplished gradually.

Identification of Piping Systems

OBJECT AND SCOPE

1. The scheme is intended to harmonize all specifications for the identification of materials conveyed in piping systems and is intended to form an acceptable basis for a universal scheme.

2. This scheme has been limited to the identification of piping systems in industrial plants and power plants, not including pipes buried in the ground and electric conduits.

DEFINITIONS

3. *Piping Systems.* For the purpose of this scheme, piping systems shall include, in addition to pipes of any kind: fittings, valves, and pipe coverings. Supports, brackets, or other accessories are specifically excluded from applications of this standard. Pipes are defined as conduits for the transport of gases, liquids, semi-liquids, or plastics, but not solids carried in air or gas.

4. *Fire-Protection, Materials, and Equipment.* This classification includes sprinkler systems and other fire-fighting equipment.

5. *Dangerous Materials.* These materials are those which are in themselves hazardous to life or property by virtue of being easily ignited or productive of poisonous gases or are in themselves poisonous. They include materials that are known ordinarily as fire producers and explosives.

6. *Safe Materials.* These products are those involving no hazard in their handling and no extraordinarily high value. A workman in approaching a piping system to make repairs will accordingly run no undue risks in breaking into a pipe bearing a safe material, even though that material had not been emptied by previous arrangement.

7. *Protective Materials.* Under this class fall materials which are piped through plants for the express purposes of being available to prevent or minimize the hazard of the dangerous materials above mentioned. Thus, a plant may have certain special gases which are antidotes to poison fumes, piped through its shops for the express purpose of release in case of danger.

8. *Extra Valuable Materials.* These might be classified with the group of the safe materials above mentioned, but where these products have a very high value, it is preferable to give them a separate major classification.

METHOD OF IDENTIFICATION

9. "At conspicuous places throughout a piping system color bands shall be painted on the pipes to designate to which one of the five main classes its contents belong. If desired, the entire length of the piping system may be painted the main classification color. (See paragraph 13.)

10. Further, the actual contents of a piping system may be indicated by, preferably, a stenciled legend giving the name of the contents in full or abbreviated form. These legends shall be placed on the colored bands. The identification scheme may be extended by the use of colored strips placed at the edges of the colored bands.

11. The bands, legends, and stripes shall be placed at intervals throughout the piping system, preferably adjacent to valves and fittings to ensure ready recognition during operation, repairs and at times of emergency."

MAIN CLASSIFICATION BY COLOR

12. This part of the scheme is intended to identify the main classes into which the materials in the piping systems belong. It establishes a basic fundamental principle applicable to all schemes for identifying piping systems and is intended to designate the pipe contents as belonging to a specific class of materials that are safe, dangerous or otherwise, depending on local conditions. The inclusion of all existing systems at present in use is made readily possible with minimum change by the adoption of the following color classification.

13. All piping systems are classified according to the character of material carried. Especially in an emergency the quick recognition of the contents of a piping system is of paramount importance. For this purpose, each piping system is classified, by the nature of its contents, into the following classifications:

Class	Color
F—Fire-protection equipment	Red
D—Dangerous materials	Yellow (or orange)
S—Safe materials	Green (or the achromatic colors, white, black, gray, or aluminum)

and, when required

P—Protective materials	Bright Blue
V—Extra valuable materials	Deep purple

14. The above colors have been chosen to identify the main classification because they are readily distinguishable one from another. Reference to Appendix B will show in addition the relation of the colors chosen to each other and to the color circle on which the color arrangement has been based.

15. Red has been assigned to fire-protection equipment because of long established custom. Yellow and orange have been assigned to dangerous materials because of all the saturated chromatic colors these have the highest coefficient of reflection under white light and can therefore be more readily recognized under the poorest conditions of illumination. Further, yellow is the traditional color of the quarantine flag and has been adopted as the caution signal for railroads and road traffic. The assignment of the other three colors follows in natural order.

DETAILED INSTRUCTIONS FOR WORKING OUT A STANDARD IDENTIFICATION SCHEME[1]

16. List all materials carried in the pipes of the system or systems.

17. Assign each of these materials to one of the five main classes: Safe products (S), Dangerous materials (D), Protective materials (P), Extra valuable materials (V), and Fire-protection equipment (F).

18. Group the materials assigned to each class for the purpose of facilitating the selection of sub-class markings.

19. Choose between the alternative methods of (*a*) color bands or (*b*) complete color painting.

20. Assign a legend or color stripe to each material listed under each main classification.

21. Refer to Appendix C and select the five colored paints which will identify the main classes and the paints to be used for the stripes if the use of stripes has been decided upon in place of legends.

22. No type of paint or other suitably colored coating is excluded. The selection of coatings comes under the jurisdiction of the supervising engineer or person in authority and may be made to meet the diverse requirements of each case. All that the scheme requires is that the dominant hue of the band shall fall unmistakably within one or the other of the five spectral regions.

23. Colors which have a total reflective value too low to permit ready differentiation at minimum illumination are excluded. Median gray, which from the physiological or visual standpoint is

[1] Note. The Sectional Committee on the Identification of Piping Systems has created a permanent organization to enable it to assist those firms and individuals who desire to consult it preparatory to the installation of this standard scheme. Address all communications to one or the other of the sponsor bodies.

situated about halfway between white and black, reflects approximately 25 per cent of the incident standard white light and is near the permissible limit of reflective value for poor illumination. The permissible limit of reflective value is provisionally established at 19 per cent.

24. An ordinary hand flash lamp when held by an operator at the reading distance may be used as the arbitrary measure of minimum illumination.

APPENDIX A

Classification of Materials Carried in Pipes

For the purpose of securing data on which to base its report, the Sectional Committee, through its Sub-Committee No. 3 on Classification, canvassed the various industries. This canvass was carried through by means of a questionnaire which was sent to a large number of companies typical of the industries handling large quantities of varied kinds of materials which are conveyed in pipes.

In the table which forms part of Appendix A is listed all the materials suggested in the replies to the questionnaire. In addition certain determinants of important physical characteristics are given together with the classification into the five main groups: (S) Safe Products, (D) Dangerous Materials, (P) Protective Materials, (V) Extra Valuable Materials, (F) Fire-Protection Equipment.

The Committee found that frequently certain materials which were at one time dangerous could fall in one or the other of the classifications. After discussing the matter with representatives of the industries the Committee has come to the conclusion that "once a dangerous material, always a dangerous material," should be the rule to be followed, and in the particular industry in which the dangerous material becomes the antidote or safe material, it should still be marked as dangerous. The few men who are in that industry should be directed by markings other than color to use it when necessary for their protection. In this way the hazard of having dangerous materials used on the wrong occasions for safe materials will be eliminated. An example of this is the use of ammonia, usually a dangerous material, as a safety material when attacking phosgene fumes. The contrary case, however, of a normally safe material becoming dangerous under certain conditions, should be met by having this material considered as dangerous only in those locations where it is dangerous, being classified by this committee as a safe material. An example is water over quicklime. In the case of drinking or service water systems with special outlets for fire protection, the Committee recommends that the fire outlets only be designated as fire protection, the remainder of the line to be classified as safe.

CLASSIFICATION OF MATERIALS CARRIED IN PIPES

Material Piped	Physical State Gas, Liquid, or Semi-Solid	Temperature of Material in Deg. Fahr. (Max.)	Pressure in Lb. per Sq. In. (Min.)	or Vacuum in Inches of Mercury or Water	Classification
Acetic acid	Liquid	Normal	30 lb.	28 in. Hg.	D
Alcohol	Liquid	Cool	.....	.....	D
Amyl acetate	Liquid	Cool	.....	.....	D
Alum solution	Liquid	.....	.....	.....	S
Acetylene gas	Gas	0 to 200	½ in. to 250 lb.	.....	D
Benzol	Liquid	Cold	Up to 80 lb.	.....	D
Brine	Liquid	Cold	About 60 lb.	.....	S
Butyl alcohol	Liquid	Cool	.....	.....	D
Bleach liquor	Solution	.....	.....	.....	D
Bisulphite liquors	Liquid	.....	.....	.....	D
Blau gas	Gas	60 to 200	½ in. to 250 lb.		D
Compressed air	Gas	80	300 (in special cases 3000 lb.)	.....	S
CO_2	Gas and liquid	−30 to −100	0 to 250 lb. per sq. in. gage	.....	D
Caustic soda solution	Solution	.....	.....	.....	D
Chlorine	Gas, liquids, and solutions	.....	.....	.....	D
Carbon bisulphide	Gas and liquid	.....	.....	.....	D
Chloroform	Gas and liquid	.....	.....	.....	D
Carbon tetrachloride	Liquid	.....	.....	.....	S
Coal gas	Gas	0 to 200	½ in. to 250 lb.	.....	D

CLASSIFICATION OF MATERIALS CARRIED IN PIPES—*Continued*

Material Piped	Physical State Gas, Liquid, or Semi-Solid	Temperature of Material in Deg. Fahr. (Max.)	Pressure in Lb. per Sq. In. (Min.)	or Vacuum in Inches of Mercury or Water	Classification
Dyes	Solution	Usually cool	.....	.....	D
Flue gas or waste heat	Gas	0 to 200	½ in. to 250 lb.	.....	D
Foamite	Liquid	Cold	Up to 100 lb.	.....	F
Glycerine	Liquid	Hot and cold	Up to 60 lb.	.....	S
HCl	Liquid	Up to 80	2 to 10 lb.	.....	D
Hydrogen	Gas	.....	.....	.....	D
H_2S Gas	Gas	0 to 150	½ in. to 100 lb.	.....	D
Intermediates	Solution	Usually cool	.....	.....	D
Lactic acid	Liquid	Normal	60 lb.	20 to 22 in.	V
Mixed acid	Liquid	Normal	30 to 80 lb.	.....	D
Miscl. solvent	Liquid	Cool	.....	.....	D
Mercury	Gas and liquid	.....	29 in. to 100 lb.	.....	D
Muriatic acid	Liquid	.....	.....	.....	D
Natural gas	Gas	0 to 200	½ in. to 250 lb.	.....	D
Nitric acid	Liquid	Normal	10 lb.	.....	D
Nitro bodies	Liquid	Cool	Up to 40 lb.	.....	D
NH_4HO_3 (molten)	Liquid	.....	None	.....	D
NH_3	Liquid and gas	−30 to 100	0 to 250 lb. per sq. in. gage	.....	D
N_2O and N_2O_3 vapor	Vapor	0 to 150	½ in. to 100 lb.	.....	D
Oils (Petroleum)	Liquid	Below 580	Below 1200 lb.	.....	D
Paper sizing solution	Liquid	.....	.....	.....	S
Pinch gas	Gas	0 to 200	½ in. to 250 lb.	.....	D
Producer gas	Gas	0 to 200	½ in. to 250 lb.	.....	D
Pyrox compounds	Liquid	Up to 80	.....	.....	D
Paint	Liquid	Cold	30 lb.	.....	D
S/A	Liquid	Up to 180	30 to 80 lb.	.....	D
Soda ash solution	Liquid	Cold	60 lb.	.....	S
Sugar juices and syrups	Liquid	195 to 200	0 to 50 lb.	.....	S
Steam	Vapor	Below 212	Below atmos.	.....	S
Steam	Vapor	212 to 800	Above atmos.	.....	D
SO_2	Gas and liquid	−30 to 100	0 to 250 per sq. in. gage	.....	D
Sulphur chloride	Gas and liquid	.....	.....	.....	D
Turpentine	Liquid	Cold	Up to 80 lb.	.....	D
Toluene	Liquid	Cool	Up to 40 lb.	.....	D
Tar	Liquid	.....	.....	.....	D
Varnish	.....	Cold and hot	30 lb.	.....	D
Vapors of valuable materials not otherwise specified	Vapor	0 to 180	½ in. to 100 lb.	.....	D
Water	Liquid	Cold	Any pressure	.....	S
		Hot	Any pressure	.....	D
Water gas	Gas	0 to 200	½ in. to 250 lb.	.....	D

EXAMPLE

In February, 1926, a Committee of the Technical Association of the Pulp and Paper Industry proposed a color code for the identification of piping in all paper and pulp mills. This proposal has been studied by the Sectional Committee and an adaptation in line with this Standard Scheme is reproduced to serve as an example of the way all the industries may make use of the Standard Scheme. Additional color stripes are indicated to illustrate the method, although the legend scheme for complete identification is considered preferable.

KEY TO CLASSIFICATION

F—Fire Protection	—Red
D—Dangerous	—Yellow
S—Safe	—Green
P—Protective	—Blue
V—Extra Valuable	—Purple

IDENTIFICATION OF PIPING SYSTEMS IN PULP AND PAPER MILLS

	Color Band	Additional Color Stripes
STEAM		
High pressure, Saturated, Superheated } 100 lb. and higher	orange	white
	.....	white-gray
Low pressure, Saturated, Superheated } 20 to 75 lb.	orange	white-black
	.....	.....
Low pressure, Saturated, Superheated } Atmosphere to 20 lb.	orange	white-green
	.....	.....
Vacuum lines, Atmosphere to 1 in. absolute	yellow	white-buff
WATER		
Fire protection	red	.....
Fresh	green	.....
Circulating	green-blue	.....
Boiler feed	green	black
Blow-off	green	brown
Make-up	green	gray
Treated	green	yellow
Filtered	green	.....
Waste or white water	green	white
Hot	green	.....
Wash	green	.....
Return condensate	green	black
Hydraulic piping: High pressure	yellow	green-red
Low pressure	green	.....
High pressure, 50 to 125 lb.	yellow	black-white
Low pressure, Atmosphere to 3 lb.	green	black-white
CLAY, ALUM, SIZE		
Alum	buff	.....
Size	green	.....
Clay	gray	white
Color	green (light)	.....
GROUNDWOOD PULP		
Grinder pressure, Water supply	green	.....
Oil supply	yellow	orange
Slush stock, No. 1 grade tailings	green	brown (gray flanges)
Low pressure	green	maroon (white flanges)
White water, High pressure	yellow	maroon (green flanges)
SULPHITE PULP		
Gas, lead, or cast iron	yellow	purple
Acid, lead, and bronze	yellow	purple-red
Blow-off—obvious	black	.....
Waste liquor, obvious unless reclaimed	green	purple-black
low pressure	green	maroon (white flange)

IDENTIFICATION OF PIPING SYSTEMS IN PULP AND PAPER MILLS—*Continued*

	Color Band	Additional Color Stripes
SULPHITE PULP		
White water, high pressure	yellow	maroon (green flanges)
Sulphite brown stock	gray	brown
Sulphite, unbleached	gray	.....
Sulphite, bleached	gray	white
Chlorine gas	yellow	yellow
Milk of lime	green	olive-white
Bleach	yellow	yellow-white
SODA PULP		
Caustic liquor, strong	yellow	brown (red flanges)
weak	yellow	tan (red flanges)
Carbonate liquor (green)	green	brown-white
Strong black liquor	yellow	brown-black
Weak black liquor	green	brown-gray
Brown stock	green	brown-buff
Unbleached stock	green	brown-gray
Bleached stock	green	brown-white
Sludge (lime mud)	green	olive
STRAW PULP		
Same as Soda Mill		
SULPHATE PULP		
Milk of lime	green	olive
OLD PAPER		
Bleach liquor	yellow	yellow-white
Soda ash	green	brown-red
Defibered stock	green	black-gray
Unbleached stock	green	green-brown
Bleached stock	green	gray-green
CONVERSION		
Slush	green	gray-tan
Paper stock	green	gray-yellow
White water, Couch pit stock, Broke stock }	green	green-white

KEY TO CLASSIFICATION

F—Fire Protection	—Red
D—Dangerous	—Yellow
S—Safe	—Green
P—Protective	—Blue
V—Extra Valuable	—Purple

APPENDIX B

Identification by Colors

For quite a long time pipe lines in various industrial plants have been painted in different colors for the purpose of ready identification. Of the various color schemes heretofore devised none has been based upon any definite fundamental principle, either scientific, psychologic, esthetic, or traditional. Because the selection of colors has been arbitrary and influenced by local conditions not common to plants in general, and because a comprehensive extension of such schemes soon involves a mass of detail which automatically renders them difficult if not impracticable, the inadvisability of recommending any of them for adoption as a universal scheme is fairly obvious.

This condition was fully recognized by the Sub-Committee on Plan and Scope. A part of its report is therefore quoted below:

IDENTIFICATION

It is obvious that to attempt to outline a code in identification, would result in a system so comprehensive that even should the supply of colors and identification symbols hold out, adoption of it would automatically be rendered impossible in those industries which do not have a major group of colors allocated to its products. It is found, however, upon investigation that any materials transported in pipes in a plant fall in one of the following classifications:

(*a*) *Safe Products.* This represents a majority of the products that are handled through a plant. These products may be defined as having no hazard in their handling and no extraordinarily high value, so that a workman in approaching a piping system to make repairs will run no undue hazard in breaking into a pipe bearing a safe material, even though that material had not been emptied by previous arrangement.

(*b*) *Dangerous Materials.* These materials are those which in themselves are hazardous to life or property by virtue of being easily flammable or productive of poisonous gases or are in themselves poisonous. They include of course materials that are known ordinarily as fire producers and explosives.

(*c*) *Protective Materials.* Under this class are materials which are piped through plants for the express purpose of being available to prevent or minimize the hazard of the dangerous materials above mentioned. Thus, a plant may have certain special gases which are antidotes to poison fumes, which gases are piped for the express purpose of affording protection in emergencies.

(*d*) *Extra Valuable Materials.* These might be classified as a group of the safe materials above mentioned, but in as much as cases came to your committee's attention where those products would have a very high value, it appeared preferable to give them a separate major classification.

(*e*) *Fire Protection Equipment.* This might properly be called a division of the Protective Materials just mentioned above, though the hazard of fire and the use of automatic sprinkler systems and other fire-fighting equipment having become so universal, it would appear better to make it a special major classification.

These five classifications or subdivisions thereof, if necessary, in the opinion of the Committee should each be given a major color, and the various subdivisions that a plant may need can be obtained by the use of numbers, names, or the like, painted in white or black upon a background of the color selected.

The immediate problem of Sub-Committee No. 1, therefore, was to select a set of colors for these five major classes that would tend to relate, in some suggestive manner, one class with another.

In seeking some common starting point, the solar spectrum was decided upon as embodying a basic principle of color arrangement that is more or less universally understood. When the colors which compose the spectrum are grouped in their natural order in the form of a circle, an arrangement is established similar to that shown in Fig. 1. This color circle may be divided into any number of given parts that may be required, but for purposes of this code, five divisions or sectors, each covering a certain spectral region, have proved quite sufficient. Each of these sectors represents one of five main classes and is capable

of subdivision, where necessary, into a larger number of hues having approximately similar dominant wave lengths, but distinguishable one from another very readily under favorable illumination (see Fig. 2). The logical arrangement of the colors shown in this circle enable complementary or opposite colors to

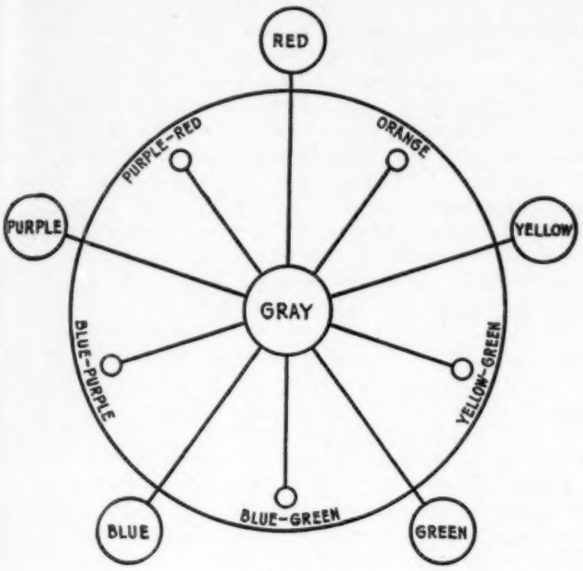


FIG. 1

be employed as designating a classification of a material directly opposite to one of the other materials appearing in one of the other main classes. For example, orange and blue are complementary or opposite colors and, in consequence, blue is selected as designating the protective materials that would be utilized to minimize hazard where dangerous materials, designated by the complementary orange color, were present. In the same manner, we find green indicative of safe products, as opposite to the complementary red which has always been associated with fire and has, in consequence, been employed to designate fire protection equipment.

With regard to durability, there seemed at first to be a general idea that the committee should select five or six indestructible pigments and have paints made from these only. A little reflection soon shows a position of this sort to be untenable, first because the resistance to attack is limited by the vehicle as well as by the pigment, second there are few substances either in the inorganic colored pigments or the organic vehicles that are equally immune to all the various forms of attack, and third, the commercial availability of the materials from which practical and economical paints can be made is by no means a negligible factor.

The committee therefore has concentrated its efforts on the presentation of a practical system having a sound claim to preference over any other heretofore suggested, and has avoided confusing the main point at issue with paint production problems which may be easy or difficult of solution according to the differing conditions in different plants. On the other hand, the committee has a detailed practical knowledge of what it is possible to produce in paints and has included in the system nothing beyond these possibilities. If a pipe contains extra hazardous material, the only fundamental requirement is that it should be yellow; the shade of yellow, the kind of pigment, and type of paint or other coating, are matters of detail coming under the province of the engineer in charge. All the system requires is that the yellow shall be of such a kind that it will not be mistaken for the green, blue, purple, or red of the other main classes.

To show a number of variations of colors and illustrate the flexibility of the system, a set of color chips on paper has been prepared in a dozen or more different colors, which is submitted with this report as part of Appendix C. The vehicle in the sepaints is highly resistant China wood oil varnish more particularly useful for interior exposure where greater resistance to moisture than is afforded by ordinary linseed-oil paint is desirable.

The paints will withstand temperatures up to 200 deg. fahr. for a reasonable time and, except the reds, temperatures even higher than 200 deg. for a shorter time. For exterior exposure linseed oil will probably continue to be the most economical all-around vehicle, but the system at all times permits any available vehicle best adapted to the prevalent conditions at any plant.

The system as suggested does not lose sight of an important fact in economical paint production, a fact which has heretofore taken a paramount position in the painting of iron and steel where the protection against corrosion has been of equal or greater importance than the color of the coating. Black, for instance, has been widely used, not only because it may be made at a low price, but also because it is practically the only paint that will withstand elevated temperatures without discoloration, has a relatively longer life under direct exposure to sunlight, and in the form as asphaltic varnishes is proof against all acids, alkalis, and sulphide sulphur compounds even in relatively strong concentrations. It is the ideal paint for pressure steam pipes, but we have taken the position that in most modern plants such pipes are insulated by various kinds of covering mostly white or nearly so, and in general not in need of any kind of paint. Such pipes may still be painted black as protection against corrosion, and the covering marked for identification by the colored bands, legends, and stripes.

The so-called metallic browns and other types of red oxide of iron have also been very largely used in low priced anti-corrosive paints. While the reflective value of the higher qualities of Venetian red is 19 per cent, or better, the darker shades run somewhat lower, and for this reason it is believed the dark

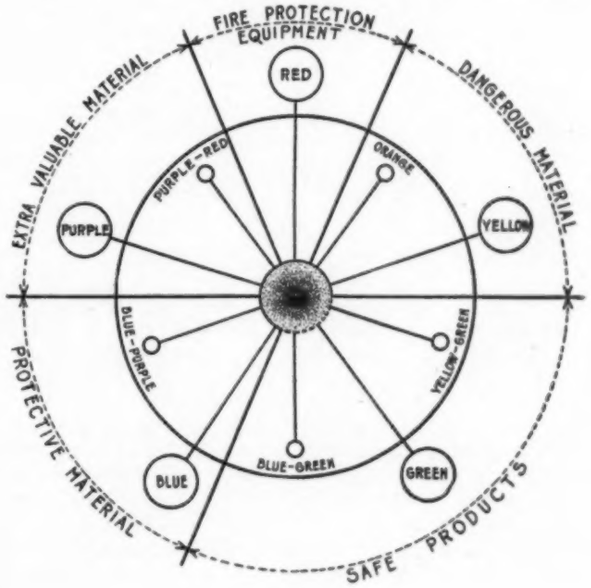


FIG. 2

browns may be excluded from the system with less sacrifice than attends any attempt to retain them.

Gold-bronze powders are of no special value and may be omitted without economic loss, but if included for any special reason would fall in the yellow or dangerous sector. Aluminum paints also are very useful in many cases and have been assigned to be used with the whites and grays to the identification of Safe Products (*s*).

APPENDIX C

Description of Colors for Special Application

To assist in the application of the standard Scheme for the Identification of Piping Systems, the following description list of fourteen colored pigments is given. This list does not cover the entire range of available colors but merely serves to illustrate the means at our disposal for meeting the more usual types of abnormal exposure conditions.

A plant atmosphere that will ordinarily support human life without material danger to general health, may at times be charged with gases or vapors that will react chemically on many paint pigments with a resultant change in color.

By far the most common of these abnormal forms of attack come from vapors that are acidic, alkaline, or sulphureted. The dry gases are far less active, but when accompanied by aqueous vapor they penetrate the paint film, and, if reactive with the pigment, cause rupture of the film and change of color by the formation of new compounds having a different volume and color from the original pigment.

If the vehicle is sufficiently resistant it may delay such action for a longer or shorter time, according to circumstances, but no paint vehicle now known is wholly impervious to osmotic penetration of this kind. In any plant, therefore, where such abnormal conditions persist, the first step is to use a vehicle having the highest practical water resistance and then select colors in such a way that the pigment will have the least reactivity with the prevailing gas. The colors here described are some of the possibilities in this direction.

Toluidin Red. Fairly fast to aqueous acids, alkalis, and sulphur. An organic pigment that will stand up as well as the vehicle. Adds materially to the life of varnish vehicles and works well with all of them.

Paranitranilin Red. Similar to the toluidin and considerably cheaper, but owing to a slight solubility in the vehicle it has a tendency to stain up through light shades or whites applied over it, e.g., white letters or aluminum stripes.

Red-Orange. A mixed pigment consisting of an organic red similar to toluidin mixed with zinc yellow. Fast to alkalis and sulphur but not to acids. Shade of orange may be adjusted to suit. Mixed with cadmium yellow in place of the zinc yellow, it becomes fast to acids as well.

Orange-Chrome Yellow. The regular color for ordinary use. Fast to alkalis but not to acids or sulphur.

Yellow. Yellow ochre toned up with bright yellow to a type commonly known as golden ochre. Ochre itself, as compared with the more highly saturated hues, is little more than a yellow-brown, but in the proposed system, where browns as distinctive colors are eliminated, the ochre falls unmistakably in the yellow sector. Owing to its general stability and low price it is the main reliance for fast yellow in situations where chrome yellows cannot be used. Like other iron compounds that contain hydroxyl groups or "chemically combined water," it is not wholly fast to sulphur. Strong ammonium sulphide darkens it somewhat, but except in extreme cases it is fast to everything. When toned up to a brighter shade, the resistance depends on the kind and quantity of toner.

Cadmium Lithopone. A combination of cadmium sulphide and blanc fixe. Fast to everything, but applicable to extreme cases only because the available supply is limited and the cost relatively high.

Chrome-Yellow-Lemon. The ordinary pigment for general use. It is fast to acids but not to caustic alkali or sulphur.

Green. Chrome oxide toned up with a little yellow to raise its total reflection value. This oxide is a moderately low priced oxide not to be confused with Vert de Guignet, a much more brilliant and expensive quality. It is fast to everything and useful in extreme cases.

Ordinary Chrome-Green Light. Fast to weak acids but not to alkali or sulphur.

Prussian Blue. A tint with a white base of Titanox. It is fast to acid, fairly resistant to sulphur and easily affected by alkali.

Ultramarine Blue. A tint with a white base of zinc oxide. It is fast to alkalis and sulphur but not to acids.

Purple. Base white of Titanox tinted with alizarine purple. Fast to everything. Shade can be adjusted by adding alizarine red in varying proportions.

Gray and Black. The achromatic colors white, black, and gray and aluminum are permitted for use in identifying safe products.

For ordinary outside exposure linseed oil is the most durable vehicle. Where higher resistance to water is required and, for interior use, China-wood-oil varnishes may be used to advantage.

APPENDIX D

Identification of Piping Systems by Legends

The first efforts of Sub-Committee No. 2 centered upon a combination of symbols or hieroglyphics along with a legend naming the nature of the containing fluid, the legend with its accompanying symbol appearing prominently at the points of supply to the piping system and at points of distribution therefrom; any further marking at intermediate points along the pipe line to consist of the symbol only.

The symbol idea was later entirely discarded since it was considered impracticable because of the great mass of detail involved, the difficulty an operating force would encounter in recalling to mind the different shapes and forms and the probable necessity for the publishing of a code book upon the part of each operating company.

The committee finally arrived at the conclusion that this form of identification marking should consist principally of a lettered legend, abbreviated or otherwise, naming the material carried in the pipe line. Where a knowledge of the direction of fluid flow may be of service it is suggested that arrows be painted on the pipe.

Attention has been given to the question of visibility with reference to pipe markings and this committee recommends that where pipe lines are located some distance above the normal line of the operator's vision that the lettering be placed below the horizontal center line of the pipe as shown in the accompanying sketch, Fig. 4. This sketch shows a group of pipe located near a wall. It is desirable, where the view is unobstructed, that the

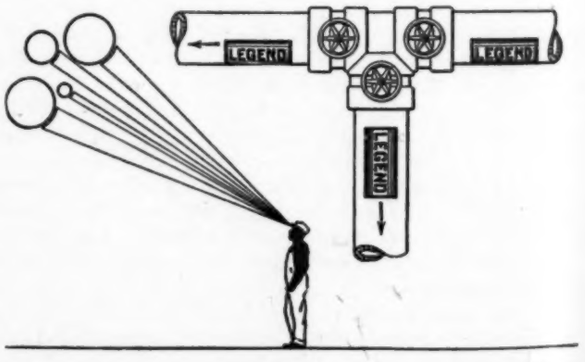


FIG. 4

lettering employed be stenciled on the two lower quarters of the pipe covering rather than one side only. The lettering in the position shown will be less liable to be obscured by dust collection or mechanical damage.

In certain types of plants it may be desirable to label the pipes at junction points or points of distribution only, as suggested in Fig. 4. In certain existing power plants the markings are repeated at intervals all along the pipe line.

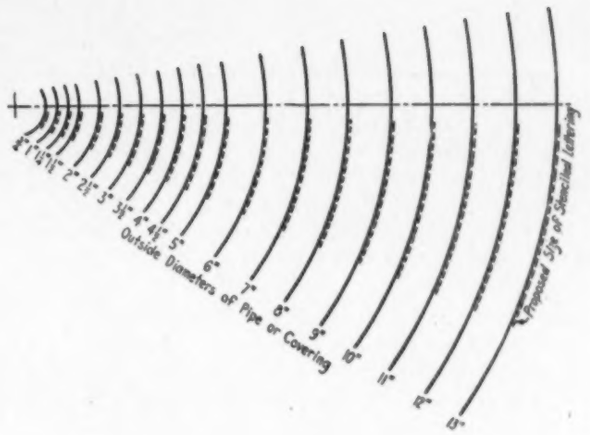
In any case, the operating man should decide both the location and the number of signs required in each particular system of piping.

Regarding the type and size of letters and numbers, we recommend the use of stencils of standard sizes easily obtained from any stencil manufacturer, ranging in height from ½ in. to 3½ in. For pipes smaller than ¾ in. in diameter requiring identifying marks we suggest the use of a metal tag with the lettering etched and filled in with enamel.

Fig. 5 gives a tabulation and a diagram of suggested heights of letters for different outside diameters of pipes or pipe coverings.

With regard to visibility, the eye as a matter of habit is most accustomed to the reading of black letters on lighter backgrounds. We therefore suggest that the black letters be either stenciled or painted on the band of main classification color when light and on a rectangular background when dark.

The color of the background and the nature of the material utilized may be that which is deemed most suitable for the purpose. Aluminum paint will without question serve very well for this purpose.



Outside dia. of pipe or covering	Size of stencil letter
¾"	½"
1"	½"
1¼"	½"
1½"	½"
2"	½"
2½"	½"
3"	½"
3½"	½"
4"	1½"
4½"	1½"

Outside dia. of pipe or covering	Size of stencil letter
5"	1½"
6"	1½"
7"	2"
8"	2½"
9"	2½"
10"	3"
11"	3"
12"	3½"
13" and over	3½"

FIG. 5

Electrical Engineers Elect Officers

Three distinguished American engineers were elected honorary members of the *American Institute of Electrical Engineers* at a meeting of its Board of Directors held June 25, 1929, during the annual summer convention of the Institute in Swampscott, Mass.

The men thus honored were: Herbert Hoover, an outstanding American engineer; C. F. Scott, engineer and inventor, head of the Electrical Engineering Department of Yale University, and past-president of the Institute and C. F. Brush, engineer and scientist, recipient of Edison Medal, Cleveland, Ohio, whose death occurred on June 15, at which time he was being balloted upon. The unanimous vote of the Directors of the Institute having been received, the Directors voted on June 25 to record Dr. Brush's name in the list of Honorary Members.

Five other Americans and three representatives of foreign countries had previously been elected as honorary members of the Institute. The Americans are J. J. Carty, Thomas A. Edison, M. I. Pupin, Ambrose Swasey and Elihu Thomson.

H. B. Smith, professor of electrical engineering, Worcester Polytechnic Institute, Worcester, Mass., and consulting engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., was elected president of the *American Institute of Electrical Engineers* for the year beginning August 1, 1929.

The other officers elected were: Vice-presidents E. C. Stone, Pittsburgh; W. S. Rodman, Charlottesville, Va.; H. S. Evans, Boulder, Colo.; C. E. Fleager, San Francisco, Calif.; C. E. Sisson, Toronto, Ont. The directors are as follows: J. E. Kearns, Chicago; W. S. Lee, Charlotte, N. C., and C. E. Stephens, New York, N. Y. G. A. Hamilton, Elizabeth, N. J., was reelected as Treasurer.

The newly elected officers, together with the following holdover officers will constitute the Board of Directors for the next administrative year, beginning August 1st: R. F. Schuchardt, retiring president, Chicago; Bancroft Cherardi, New York; W. T. Ryan, Minneapolis, Minn.; B. D. Hull, Dallas, Tex.; E. B. Merriam, Schenectady, N. Y.; H. A. Kidder, New York; G. E. Quinan, Seattle, Wash.; I. E. Moultrop, Boston, Mass.; H. C. Don Carlos, Toronto, Ont.; F. J. Chesterman, Pittsburgh, Pa.; F. C. Hanker, East Pittsburgh, Pa.; E. B. Meyer, Newark, N. J.; H. P. Liversidge, Philadelphia, Pa.; J. A. Johnson, Niagara Falls, N. Y.; A. M. MacCutcheon, Cleveland, Ohio, and A. E. Bettis, Kansas City, Mo.

Carrier Opens New Western Office

The Carrier Engineering Corp., specialists in air conditioning, whose main offices and laboratories are in Newark, N. J., has opened a permanent engineering and sales office in the Buhl Building, Detroit, under the direction of Herbert Peacock, who had previously been assistant to the sales manager of the company.

At intervals during the past year the company has had temporary offices in Detroit while air conditioning, cooling and ventilating installations were in progress in the Parke Davis Laboratories.

President Hoover Appoints Delegates to Tokio

The United States will be officially represented at the World Engineering Congress which is to take place in Tokio, October 1929, by seventeen prominent engineers appointed by President Hoover.

Seven of the delegates are from Washington, Commissioner Elwood Mead, George Otis Smith, George K. Burgess, O. C. Merrill, Major-General Edgar Jadwin, Scott Turner and John Hays Hammond.

The New York delegation consists of Elmer A. Sperry, Frank B. Jewett, John W. Lieb, Maurice Holland, Daniel L. Turner, Byron Eldred, J. V. W. Reynders and Mark Requa.

John R. Freeman, Providence, R. I., and Dugald C. Jackson, Boston, Mass., comprise the two remaining members of the delegation. The delegates will sail from San Francisco, Calif., on October 10, 1929.

Local Chapter Meetings

Illinois Chapter

May 17, 1929. The final meeting of the year was held at the Glen Oak Country Club, Glen Ellyn, at which the annual Golf Tournament and Dinner Dance were given.

The meeting was attended by 85 members and guests, and it was agreed that a very enjoyable time was had.

Kansas City Chapter

May 27, 1929: At the May 27 meeting of the Kansas City Chapter of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS the following officers were elected for the coming year: C. C. Clegg, *President;* E. K. Campbell, *Vice-President;* W. C. Plass, *Treasurer;* F. A. Kitchen, *Secretary;* the *Board of Governors* consists of H. C. Henrici, Henry Nottberg and B. C. Naylor.

These officers take charge at once, and hold office until after the May meeting in 1930.

Pacific Northwest Chapter

June 6, 1929. This, the Annual Meeting of the chapter, was held after a banquet at the New Washington Hotel, Seattle. Minutes were approved and committee reports received, and the Secretary presented several matters of interest arising through correspondence. The local Code Committee, consisting of W. E. Beggs, W. W. Cox and E. L. Weber, was continued. The tellers of election reported the following officers for the ensuing year 1929-30:

President—E. L. Weber.
Vice President—E. O. Eastwood.
Secretary—M. Anderson.
Treasurer—W. W. Cox.
Board of Governors—W. L. Dudley, C. F. Twist, W. E. Beggs.

The retiring President, W. L. Dudley, and the President elect, E. L. Weber, then addressed the chapter.

The program was concluded by a general discussion of the first year of existence of the Pacific Northwest Chapter and the status of the heating and ventilating engineer, in which practically every member present participated.

Philadelphia Chapter

May 9, 1929. The meeting was devoted primarily to golf and a visit of inspection to the Frost Research Laboratory.

During the afternoon about forty golfers spent a very enjoyable three hours digging up the fairways and rough, at the Plymouth Country Club. Dinner was served to about eighty members in the Club House, after which a short business session was held.

The Chapter then moved by motor to the Frost Research Laboratory in Norristown, where competent guides were waiting to explain the various features of the Laboratory and to give detailed information on the many makes and types of stokers being tested for residential and small boiler service. Keen interest was shown by all present in the modern and complete apparatus available for experimental and test purposes, and Mr. Frost was the recipient of numerous compliments.

During the evening, Mr. Mensing read a communication from President Lewis, urging as many members of the Philadelphia Chapter as possible, to attend the Summer Meeting at Bigwin Inn, Lake of Bays, Ontario, Canada.

Cigars, cigarettes and ginger ale were provided in ample quantities by Mr. Frost, and at the end of our visit the meeting was voted a great success, and the wish expressed that other similar outings be held in the future.

Western New York Chapter

May 13, 1929. The largest gathering of the year turned out to meet the National Officers of the Society and Dean Anderson with his University of Kentucky Senior Engineers, there being over 175 members and guests present. The Meeting was held at the Elks' Club, Buffalo, N. Y.

The evening was entirely a social one, the talks being extemporaneous, short and snappy; and the entertainment delectable. President Dyer called attention to the Semi-Annual Meeting of the Society at Bigwin Inn, Ontario, June 26-28, 1929. Several members of the Ontario Chapter were present and outlined the details of the convention. From the enthusiasm indicated, the Western New York Chapter will be well represented.

President Dyer introduced some of the notables present including W. H. Carrier, E. B. Langenberg, L. A. Harding and Dean Anderson. Dean Anderson told of the ideals of Kentucky Engineers, and the value of the annual inspection trips through industrial centers. He introduced the other members of the faculty of the Engineering School of the University of Kentucky, who were with the group on this trip. N. L. Nallau ably responded for the Senior Engineers.

Fred Zander, advertised as "Buffalo's De Wolf Hopper" lived up to his reputation and alternately brought tears and laughter to his listeners by his eloquence.

National President Thornton Lewis lauded the Western New York Chapter for its accomplishments, and called attention to the number of University of Kentucky men who have served their apprenticeships in Buffalo, and who have made worthwhile accomplishments.

Wisconsin Chapter

May 27, 1929. The members of the Chapter were guests of one of their fellow members, J. G. Shodron of Fort Atkinson, Wis., and spent the afternoon and evening studying the research and development work on the heating and ventilation of farm buildings of the James Manufacturing Company, of which Mr. Shodron is Chief Engineer.

After going through the two large plants of the company, the party visited the research laboratory where they inspected a new system of ventilation for farm buildings made possible by the specially conducted laboratory equipment for measuring air movement and testing the efficiency of this system at various stages of its development.

The *Infiltronometer* or universal air testing machine was of particular interest to those present. This apparatus contains a chamber in which weather conditions ranging from balmy breezes up to hurricanes and cloudbursts can be artificially maintained.

It is also possible to test large sections of walls, roofs and building materials in this unique piece of apparatus to determine the amount of infiltration and exfiltration under various conditions. Mr. Shodron demonstrated his "rain maker" which is capable of producing a rate of precipitation of 12 in. per hr., which is twice as great as that ever reported in the entire history of the U. S. Weather Bureau for any locality.

It was stated that there are only three other machines in the United States where infiltration of air through materials can be measured, and that this is the only one known where tests under both wind and rain conditions are being made to ascertain air and rain in-leakage.

The importance of fresh air to farm animals was stressed, and the manner of supplying it to animals in the proper volume and without drafts, was explained. The majority of farm buildings are ventilated by the *gravity system*, the motive power being obtained from the heat generated by the animals. A certain

GROUP OF WISCONSIN MEMBERS ATTENDING MAY CHAPTER MEETING

amount of this heat is expended in maintaining the body temperature of the animals, and part of it is lost through the walls and ceiling. Hence, only a portion of the total heat generated by the animals operates the ventilating system. Therefore, it is pointed out that the degree of insulation of the wall and ceiling construction of the barn or other structure has an important bearing on the maintenance of satisfactory conditions.

After the dinner at the Blackhawk Tavern at Fort Atkinson, a short business meeting was held. Professor Larson was elected official delegate of the Wisconsin Chapter for the Summer Meeting of the Society. It was agreed upon that the annual picnic of the Chapter was to be held June 17, 1929.

World Engineering Congress

A review of outstanding industrial and engineering developments in the United States during recent years is contained in the 80 scientific papers prepared by American engineers for presentation at the World Engineering Congress convening at Tokio on October 30, 1929, next.

That this review will be an important contribution to the world's engineering knowledge is indicated by the names of the authors and the titles of the papers, which cover a wide variety of subjects and include virtually every branch of engineering. Rapid transit development, airplane design, interconnection of the nation's great power systems, the construction of bridges and tunnels, river and harbor engineering, raw materials, irrigation, safety in dam and reservoir construction, sanitary engineering, metallurgy, refrigeration, mining, structural engineering, telephones and radio transmission, marine engineering and ship design—these are a few of the highlights selected from the first group of papers assembled by the technical program committee of the American Committee in charge of arrangements for participation in the Congress.

Among the contributors are Dr. Elmer A. Sperry, inventor of the gyroscope, and chairman of the American Committee; Dr. Frank B. Jewett, vice-president of the American Telephone and Telegraph Co., in charge of research and technical development; C. M. Keyes, president, Curtis Airplane and Motor Co.; John I. Stevens, former chief engineer of the Panama Canal, and noted railway expert; Ralph Modjeski, builder of the Delaware River Bridge at Philadelphia and many other notable bridges; Ole Singstad, chief engineer, N. Y. State Bridge and Tunnel Commission, and builder of the Holland Vehicular Tunnel under the Hudson River; Dr. George Otis Smith, director of the U. S. Geological Survey; Willis R. Whitney, director of Research for the General Electric Company; Major-General Edgar Jadwin, chief of engineers, U. S. Army; Robert Ridgway, chief engineer, New York City Board of Transportation; Rear Admiral D. W. Taylor, former chief constructor, U. S. Navy, and a member of the National Advisory Committee for Aeronautics; Prof. D. C. Jackson, of Massachusetts Institute of Technology, School of Electric Power Production and Distribution; C. E. Grunsky, of San Francisco, civil engineer and consultant on municipal engineering; Farley Osgood, of New York, consulting electrical engineer; Allen Hazen, of New York, hydraulic engineer and expert on dams.

The subject of lightning will be dealt with in a paper by F. W. Peek, Jr., consulting engineer to the General Electric Co., who recently announced the development of artificial lightning generators capable of producing a bolt of 5,000,000 volts. G. W. Fuller, consulting engineer of New York, will present a paper on public health engineering; Roy V. Wright, of New York, managing editor of Railway Age and other technical publications, will deal with railroad equipment; George A. Orrok, consulting electrical engineer of New York, will discuss power plants; L. P. Alford, consulting editor, McGraw Hill Publishing Company, has prepared a paper on the subject of scientific industrial management; H. P. Moore, research professor of engineering materials, University of Illinois, will contribute a paper on "The Development of the Science of Structural Materials".

The technical sessions of the World Engineering Congress will be held during the first week of the meeting, beginning November 1, 1929. The American delegation, which now consists of 250 engineers and their families, will embark for the Congress from San Francisco on two special ships, sailing October 10th.

Buffalo Forge Head Dies

HENRY W. WENDT, a prominent member of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, and a leader in the heating and ventilating industry, died at his home in Buffalo, N. Y., on June 12, 1929, after a brief illness.

Mr. Wendt would have reached the age of 67 in a few days, and during his entire business life had been connected with the

HENRY W. WENDT

Buffalo Forge Co., of which he had been the active head for many years.

Mr. Wendt was a natural engineer and was placed in charge of the manufacturing activities of his company soon after it was established. He frequently introduced new methods into the various departments, and was known as an expert foundryman. In later years he was president of the *American Foundrymen's Association*, and under his direction the foundry achieved a reputation for turning out difficult castings.

It was at Mr. Wendt's own suggestion that the Buffalo Forge Co. first engaged in the manufacture of fans and heating apparatus, and for many years he was the only salesman for fan equipment, as well as playing the parts of designer and manufacturer.

A great many inventions of practical value have been placed to the credit of Mr. Wendt, and to an unusual degree he possessed the combination of an inventive mind with a sense of practical value, which undoubtedly had much to do with his success. However, those who knew him best like to think of the man himself and the fairness and frankness with which he met every situation, business and personal. Never one to harbour resentment, it was hardly possible for any situation to arise which would ruffle his composure. When the occasion came, he would give his opinions and the reasons for them, which were usually excellent, but he did not insist on having his own way, nor was it often necessary.

Always fair and considerate in his personal contacts, friends and casual acquaintances will perhaps think of him most often in that light, while his business associates also had frequent occasion to realize the patience that he displayed.

Mr. Wendt was for many years especially interested in research work, though he did not designate it by that name. Facts were what he wanted, and he was willing to spend money to obtain them, which was rather unusual thirty years ago. At that time accurate knowledge of fan performance was limited but was nowhere available in published form, but the Buffalo Forge Co. was the first to publish performance data for general use. When the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS established the Research Department and asked the industry for help, Mr. Wendt was the first to pledge his support over a term of years and to urge other manufacturers of ventilating apparatus to do the same. This support has never been withdrawn.

In addition to his activities in the Society, Mr. Wendt was the first president of the *National Fan Manufacturers Association*, was one of the founders of the *Hydraulic Association*, and was a member of the *American Society of Mechanical Engineers*, and other engineering and trade associations. While never seeking honor or position, his interest and support were active in these, as well as in personal and business connections in his own city.

Mr. Wendt recognized no distinction of position in his contacts with men. Knowing many of his employees personally, he could call them by name as he went through the plant, and it was an everyday occurrence for shop men in working clothes to walk, unannounced, into his office to see the "Big Chief" about some personal matter, or with a suggestion for an improvement. There are many who will miss him in the industry with which he was so closely identified.

L. B. Miller Retires from McDonnell & Miller

Announcement was made on June 20, that the co-partnership of McDonnell & Miller, 400 N. Michigan Ave., Chicago, Iil., and 5936 Grand Central Terminal Building, New York City, was dissolved by mutual consent and that Mr. E. N. McDonnell will continue the business under the old firm name.

President Lewis Visiting England and France

On July 6 when President Thornton Lewis sailed for England on the S. S. Minnewaska, he carried with him greetings of the members of the American Society of Heating and Ventilating Engineers to the Officers and Members of the Institution of Heating and Ventilating Engineers of Great Britain, as prepared at the first meeting of the Society outside of the United States, recently held at Bigwin Inn, Lake-of-Bays, Ontario, Canada.

English members of the American Society under the direction of W. Nelson Haden have arranged for a meeting with President Lewis and the officers of the British Institution of Heating and Ventilating Engineers, on July 18, in London.

When President Lewis arrives in France he will be greeted by the French members of the American Society who have invited him to attend a meeting on August 12 in Paris. A message from M. Beaurrienne states that the Society members in Paris welcome the opportunity to meet the President and send their greetings and good wishes to the members of the American Society.

Electric Light's Golden Jubilee Stamp

Postmasters and others connected with the U. S. Postal Service have been notified that the Department is issuing a new 2-cent postage stamp to commemorate the 50th anniversary of the producion of the incandescent lamp invented by Thomas Alva Edison.

The new stamp is the same size as the 2-cent ordinary stamp, and is printed in red ink. The central design is a picture of the original lamp. The new Edison commemorative stamp was first sold June 5, 1929, at the post office at Menlo Park, N. J.

CANDIDATES FOR MEMBERSHIP

The Constitution of the Society, as now amended, requires the following mode of procedure in voting on applicants for membership in the Society. All applications for membership are to be sent to the Secretary and the names of applicants and their references shall be printed in the next issue of the Journal of the Society or sent to the members in other approved manner as ordered by the Council. When replies are received from references, the Candidate's application shall be submitted to and acted upon by the Membership Committee as soon as possible.

When the Membership Committee has acted favorably upon a Candidate's application and assigned his grade the Council shall vote upon the election of the proposed Candidate for membership by letter ballot. During the past month 14 applications for membership have been received and the names of these men and their sponsors are published in the following list.

Members are requested to scrutinize the list with care. The Membership Committee, and in turn the Council, urge the members to assume their share of the responsibility of receiving these candidates into membership by advising the Secretary promptly of any whose eligibility for membership is in any way questioned. All correspondence in regard to such matters is strictly confidential, and is solely for the good of the Society, which it is the duty of every member to promote.

Unless objection is made by some member by August 2, 1929, these candidates will be balloted upon by the Council. Those elected to membership will be notified by the Secretary, immediately after election.

	REFERENCES	
	Proposers	Seconders
DARLING, ARTHUR BALFOUR, Mgr. of Webster Systems, Darling Bros., Ltd., 140 Prince St., Montreal, P. Q., Can.	H. J. Church Harry H. Angus	M. Barry Watson Arthur S. Leitch
DINGLEMAN, CHARLES S., Cons. Engr., 1132 Fidelity-Philadelphia Trust Bldg., Philadelphia, Pa.	Benj. Adams Albert J. Nesbitt	Raymond E. Jones Franklin W. Wandless
FEELY, FRANK J., Mgr. of Sales, The Taylor Supply Co., Detroit, Mich.	Wm. G. Boales E. H. Clark	R. F. Connell W. A. Rowe
FLEMINGS, JOHN A., Mgr., N. E. Br., Spencer Heater Co., 216 Tremont St., Boston, Mass.	F. R. Ellis E. C. Whitaker	Alfred Kellogg P. A. L. Foulds
FORTUNE, J. ROBERT, Gen. Sales Mgr., Wickes Boiler Co., Saginaw, Mich.	J. R. McColl R. S. Wilde	H. L. Walton R. Collamore
GROSS, SAMUEL, Treas., Sheffler-Gross Co., Inc., 203-11 Drexel Bldg., Philadelphia, Pa.	M. Sheffler Raymond E. Jones	Franklin W. Wandless A. E. Kriebel
GURNEY, EDWARD HOLT, Pres., The Gurney Fdry. Co., Ltd., 500 W. King St., Toronto, Ont., Can.	E. B. Sheffield Melvern F. Thomas	M. Barry Watson Harry H. Angus
HARDINGE, FRANKLIN, Pres. & Gen. Mgr., Hardinge Bros., Inc., 4149 Ravenswood Ave., Chicago, Ill.	Homer R. Linn	
ROBERTS, CHARLES A., Resident Mgr., Imperial Iron Corp., Ltd., Toronto, Ont., Can.	W. R. Blackhall Harry H. Angus	Arthur S. Leitch James S. Paterson
SCHWARTZ, JACOB, 30 West 27th St., Bayonne, N. J.	Anton J. Rizzi *(Non-Member)* P. D. Butler	
STRICKLAND, ALBERT W., Owner & Mgr., A. W. Strickland Plbg., Htg. & Elec. Co., Big Timber, Mont.	Andrew W. Allen *(Non-Member)* Dr. R. G. Harris *(Non-Member)*	H. McArthur *(Non-Member)* Dr. C. R. Davenport *(Non-Member)*
SWAN, ERNEST HERIOT, Senior Partner, W. A. Swan & Sons, 122 Unley Rd., Unley, South Australia, Australia.	Clinton H. Quirk Orian O. Oaks	T. W. Reynolds Carl Flink
TABBINER, HAROLD, Salesman, Crane, Ltd., 306 Front St., W., Toronto, Ont., Can.	Melvern F. Thomas Harry H. Angus	A. J. Dickey
THAYER, ALLEN JACKSON, Carman-Thompson Co., Lincoln St., Lewiston, Me.	Phillips Eaton Coll T. Flint	Wm. T. Jones

Candidates Elected July, 1929

In the past issues of the Journal of the Society there were posted among the list of Candidates for Membership, 6 candidates for election in the different grades of Membership, whose names have been balloted upon by the Council. We are now instructed by the Council to post herewith, as required by Art. II, Sec. VIII, of the By-Laws, the following list of candidates elected:

MEMBERS

BLACKBURN, EDWIN CARL, JR., 35 Miller Pl., Hempstead, L. I., N. Y.

BUTLER, CHARLES WILLIS, Sales Engr., American Blower Corp., 6000 Russell St., Detroit, Mich.

CUMMINGS, CHARLES ANTHONY, U. S. Radiator Corp., 127 Campbell Ave., Detroit, Mich.

DRESEN, WILLIAM D., Inland Heating Co., 1120 N. Cicero Ave., Chicago, Ill.

MESSMER, GEORGE ELLIS, Sales Mgr. & Htg. Engr., Bridge & Beach Mfg. Co., 4204 N. Union Blvd., St. Louis, Mo.

JUNIORS

FIFE, GEORGE DONALD, Carrier Engrg. Corp., 850 Frelinghuysen Ave., Newark, N. J.

Heating·Piping
and Air Conditioning

EDITORIALS

Congestion, Noise, Impure Air

A recent letter from Dr. Alexis Carrel of the Rockefeller Institute for Medical Research, New York City, to this publication states:

"My opinion that modern cities are not suitable for the sheltering and breeding of human beings is based on the fact that the size of the buildings has caused too great an increase in the density of the population. The area of the streets is not sufficient for the number who dwell in the houses. Motor cars and trucks are not segregated. Their noise and fumes are injurious to the health of the people. The apartments are almost as noisy as the streets, and the atmosphere within doors is rendered toxic by carbon monoxide and gasoline fumes. No provision is made to supply the building with pure air, and to protect the people from the noise. Moreover, families are packed into too small quarters. No new conceptions have been evolved in the planning of cities which would allow men to keep their health and nervous equilibrium, and to propagate a sound race in the changed conditions of the modern world."

Dr. Carrel is a man of international repute. His criticisms are specific. The three dragons which he attacked are congestion, noise and unhealthful air. They are an unholy trinity, and like, the sides of a triangle, lean upon each other.

It is interesting to note in the meantime that this triad has been selected for special attack by a man of such high standing. It is interesting particularly to air conditioning engineers because they are attacking the same triad.

Air conditioning closes windows and keeps out noise. Air conditioning provides healthful air. Air conditioning lays low congestion, the third side of the triangle.

It would appear after reading Dr. Carrel's letter that air conditioning is not a superficial science, a luxury or a twentieth century idea, but is a fundamental factor in the welfare of the human race.

Labor Becomes an Engineer

At the recent meeting of the American Society of Heating and Ventilating Engineers in Canada, there were two guests whose presence would have seemed strange indeed not many years ago. They were representatives of the United Association of Journeymen Plumbers and Steam Fitters. They had been elected by their brother members to attend this convention of engineers, sit in at the meetings, read the papers, hear the discussions and bring back home information on any engineering developments in heating that would be apt to affect their trade. And when we say "affect their trade," we do not mean that the concern of these two men was to look for processes that might cut down the amount of labor on a job but to look for worth while progress with which the journeymen could associate themselves and thus aid in the advancement of heating.

Too often we think only of the manufacturer, the engineer and the contractor as the groups from which we expect engineering developments and among which we encourage co-operation. Too often the journeyman is overlooked. Yet it can be the journeyman fitter in the employ of contractor or industrial plant on whom the major success of an installation can depend. It can be the journeyman fitter from whom suggestions can be expected that will save time and money, improve efficiency and solve problems in an installation. Generally those suggestions are the result of the practical experience of such men. The attendance of labor's representatives at engineering meetings, however, augurs a combination of practical experience and engineering knowledge from which great things can be expected.

Piping Codes

As most engineers in the piping field know, a committee on a code for pressure piping has been functioning since its appointment in March, 1926, to represent organizations of manufacturers, users, and general interests in the drafting of national codes for power piping, hydraulic piping, gas and air piping, refrigerating piping and oil piping. This committee, consisting of sub-committees, is sponsored by the American Society of Mechanical Engineers under the procedure of the American Standards Association.

These codes are aimed to standardize minimum safety requirements for these various piping systems through a classification of material specifications and standard dimensions for pipes, fittings and valves, together with general requirements for hangers, coverings, inspections, tests, etc. Certain ones of these codes are in tentative form and have been circulated among interested parties for criticism and suggestions. For instance, the code for oil piping systems has had such circulation. We understand that the code for power pip-

ing and the one for gas and air piping have received or are ready for similar treatment. The criticism received will have the study of the proper committee and will be incorporated in the final draft. With the necessary changes, these codes will be made standard and presented for adoption and practice.

Whatever may be the feeling of manufacturers, users or others in regard to codes, with the impositions they might mean of inspections, it is apparent that there are going to be codes of one sort or another, and it is, therefore, desirable to make them conform to the interests of the greatest number. For instance, certain states have or are considering piping codes. There are variations in the requirements of these various codes, with the result that it is difficult for manufacturers to standardize on the production of pipe, valves, fittings, etc. One state requires one type, others another.

If only for the reason, therefore, that, if there are to be codes, they should be standardized on a national basis, we feel that the work of this committee on a code for pressure piping should receive the support and interest of all concerned with piping.

Wasteful Economy vs. Economic Wastefulness

Our points of view are changing with reference to economy. Americans, said to be the most wasteful people in the world, are at the same time the most economical. Ponderous mechanical equipment is scrapped to be replaced by newer equipment which will save another point in thermal energy.

A group of men propose to "waste" millions of dollars on research in building construction. Their objective is human habitations of great economy,—at 1/3 the present cost,—parts made in factories,—based upon scientific principles and made with automatic machinery. In every field this willingness to "waste" in order to save is evident.

District heating, for instance, has been feeling the influence of this wasteful economy, according to John W. Meyer, retiring president of the National District Heating Association. In his address at the district heating school held at Purdue University, May 20 to 25, 1929, Mr. Meyer stated that heretofore district heating has been allowed to drift. Boilers have been inefficient, steam flow meters have not been so dependable and economy has been employed that has resulted in wastefulness rather than "wastefulness" that has resulted in economy.

Expensive plans have been made and distribution systems have been installed without due regard to their efficiencies. The resulting service was not satisfactory as the rates charged were not high enough to maintain a proper standard of service. Some contracts were made on an increment basis, at a flat charge, regardless of the amount of service rendered. Sales resistance was high and service was not appreciated.

But now there is a very noticeable change. Due to better equipment and better engineering there are marked improvements in plant performance,—in the operation of distribution systems, and there have been great advances in meter accuracy. As a result, evidences of growth of district heating, Mr. Meyer stated, are apparent in nearly every major city.

Economical wastefulness has superseded wasteful economy. It is a trend apparent in every field.

Taking the Manufacturer's Advice

To the Editor:—

The modern manufacturer has built his business around years of experience. He has gathered into his organization men of various capabilities, each virtually a specialist in his own line. He has taken advantage of past experiences in the application of his product to the uses for which it is intended, for he is jealous of his reputation.

The materials which enter into the manufacture of his product are carefully selected and must pass through rigid tests and analysis before being approved for use, as the modern way is to furnish the best, knowing full well that it costs more to make good on a poor product than to make a good product in the beginning.

That manufacturer who thinks he can foist upon the public an article which will not stand up in use, and the failure of which can be blamed upon faulty installation or improper operation, is not destined to success, but he who makes his goods the best he knows how is assured of that fame credited to the well known maker of mouse traps.

However, and here is something which every user should read and understand as truth, the manufacturer of good goods must be credited with sincerity and must be recognized as an authority in his line unless and until the contrary is proven.

In heating and ventilating, the manufacturer's goods have to be installed by mechanics who, worthy of their hire and clever in the art, can not all be credited with knowledge about everything.

Too often some of these men of brawn, while possessed of considerable information, will set themselves up as experts whose ability should not be assailed. They disregard the instructions of their employers and disdain the recommendations of the manufacturer, using their own methods of application which frequently prove incorrect. Many such men are experts and their knowledge and skill can solve a problem that might baffle their employer and the manufacturer. But there are some who have been responsible, in the experience of the writer, for the necessity for expensive changes, the burden of which falls upon the boss.

The wise man will welcome suggestions and recognize the fact that he can be relieved of much responsibility if he uses the manufacturer's data or diagrams or charts.

Fortunately, this little lecture will apply to a comparative few, for the average artisan is broad minded enough and keen enough in his own interest to take advice. It is the minority to whom we refer and whom those higher up in every organization should watch carefully, for such errors eat into the profits.

—John F. Hale.

PRACTICAL PIPING PROBLEMS

Heating Passenger Cars
Fire Protection Piping for Dust Removal Systems

by
W. H. WILSON

Heating Passenger Cars

WHEN passenger cars are in operation (in transit on the train) the steam for heating is supplied from the locomotive through the "train line," a pipe line (usually 1½-inch pipe) passing under the car from end to end, each end terminating in a steam hose connection. Metallic hose has been tried out and flexible or ball joint and metallic connections are being used by some railroads instead of regular hose. By connecting the steam hose, a continuous steam supply line is made, reaching from the locomotive to the rear end of the train. Each passenger car has suitable branch connections from the train line to furnish heat for the car.

The end valves on each car (at the steam hose) are left open when train is made up to provide a continuous passage of steam with the exception that the valve on the rear end of the train is closed to prevent the escape of the steam. This valve, though, is arranged to leak a little steam to prevent freezing.

All passenger cars are equipped with an emergency stove so that in case a car is set out on a side track, or the locomotive for some reason is detached from the train, the stove can be fired up and heat maintained, while this emergency condition exists.

Refrigeration cars and similar cars that are sometimes run on passenger trains are equipped with steam train line only—no branch pipes—so that steam can be transmitted throughout the entire length of the train as these cars are almost invariably run at the head of the train.

When passenger cars remain in the yards or side tracks the train line is connected to a yard steam line, usually located in a tunnel, which supplies the steam for heating, usually from a stationary boiler plant. In order to effect a saving in heating, a system that is used in a great many cases and rapidly increasing is to equip each car with a special thermostatically controlled valve that maintains the temperature above the freezing point, usually 50 degrees F. when the car is standing in the yard.

Before a train is scheduled to leave, an invariable practice is to test out the air brake equipment, either by connecting the air brake train line to the yard air supply line or by bringing the locomotive up and connecting it to the train. The locomotive is nearly always connected to the train thirty minutes before the train is scheduled to leave. From this time until the locomotive is disconnected at the train's destination the air brake train line is always charged with compressed air at the required pressure. This is essential. It would be impossible to operate a train in this day and age without compressed air for the air brakes.

The thermostatically controlled steam supply valve previously mentioned has a small pipe connection from the air brake train line which allows air pressure to reach the valve. The valve is so arranged that when the air pressure reaches this valve the setting of the thermostat (which controls the steam supply for heating the car) is automatically changed (by the air pressure) from 50 degrees to 70 degrees or at whatever temperature the operators may elect to set the thermostat (70-72-or 75 degrees). Passenger cars are sometimes heated by what is known as "straight steam"—steam direct from the engine to pipe coils in each car at plenty of pressure to force its way through. This is the cheapest system to install and is used in some cases, but has the disadvantage that when the train is going up steep grades the engine crew shuts off the heating system to help out the engine and engine crew.

A pressure system of hot water was used extensively some years ago and is still in use in some cars.

At the present time, steam at atmospheric pressure, or what is known as the vapor system, is supplanting many of the former methods.

Fire Protection Piping for Dust Removal Systems

WOOD working plants require equipment for removing the sawdust, shavings and cuttings from the wood working machines. This equipment consists of a blower and system of piping. Each machine has a suitable pipe connection and the suction from the blower removes the sawdust and shavings as they are made by the machine tools; and then the blower forces them through a main pipe line to a place of disposal.

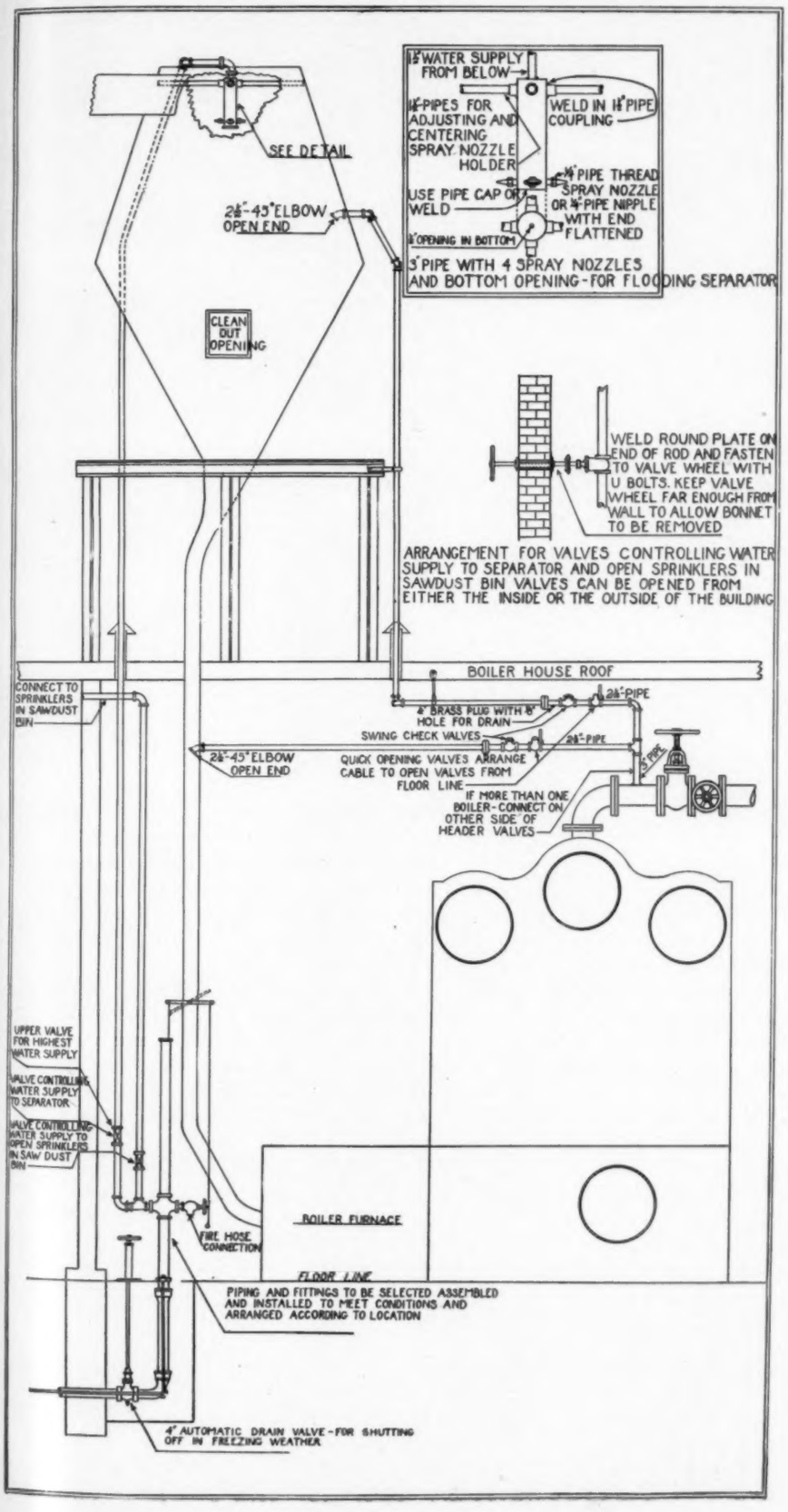
A common practice for disposing of the accumulation of shavings and sawdust is to pipe them to the boiler house and get the benefit of their fuel value. In this connection, it is necessary to provide a suitable separator which will allow the air to pass out of the piping into the atmosphere and the sawdust, shavings and dust either go into the boiler as needed, or into a storage room or sawdust bin for use as required.

A universal practice is to lead the main shavings pipe overhead, or in a tunnel, to the boiler house and then to the roof of the building and there install a suitable separator or dust collector, with a number of baffle plates or deflectors inside of the separator so arranged that the inlet pipe causes a whirl or centrifugal force. This force causes the air to pass out at the opening on the top and, their velocity being reduced by the shape of the separator, the sawdust, shavings and dust to fall

to the bottom, where the pipe, leading to the boiler furnace or sawdust bin, is connected.

In our experience we have known of a number of fires that have occurred in these shavings separators and connecting pipes. Sometimes, when the gate controlling the shavings supply to the furnace is shut off before the pipe from the furnace is removed, the flame will travel back through the furnace pipe to the separator. The boiler room employes often refuse to take the blame and insist that the fire was caused by spontaneous combustion.

At any rate, a fire in the separator or connecting piping is liable to be troublesome, if not


1" WATER SUPPLY FROM BELOW
1" PIPES FOR ADJUSTING AND CENTERING SPRAY NOZZLE HOLDER
WELD IN 1" PIPE COUPLING
USE PIPE CAP OR WELD
¼" PIPE THREAD SPRAY NOZZLE OR ¼" PIPE NIPPLE WITH END FLATTENED
1" OPENING IN BOTTOM
3" PIPE WITH 4 SPRAY NOZZLES AND BOTTOM OPENING - FOR FLOODING SEPARATOR
SEE DETAIL
2½"-45° ELBOW OPEN END
CLEAN OUT OPENING
WELD ROUND PLATE ON END OF ROD AND FASTEN TO VALVE WHEEL WITH U BOLTS. KEEP VALVE WHEEL FAR ENOUGH FROM WALL TO ALLOW BONNET TO BE REMOVED
ARRANGEMENT FOR VALVES CONTROLLING WATER SUPPLY TO SEPARATOR AND OPEN SPRINKLERS IN SAWDUST BIN VALVES CAN BE OPENED FROM EITHER THE INSIDE OR THE OUTSIDE OF THE BUILDING
BOILER HOUSE ROOF
CONNECT TO SPRINKLERS IN SAWDUST BIN
2½" PIPE
4" BRASS PLUG WITH ⅛" HOLE FOR DRAIN
SWING CHECK VALVES
2½"-45° ELBOW OPEN END
QUICK OPENING VALVES ARRANGE CABLE TO OPEN VALVES FROM FLOOR LINE
IF MORE THAN ONE BOILER - CONNECT ON OTHER SIDE OF HEADER VALVES
UPPER VALVE FOR HIGHEST WATER SUPPLY
VALVE CONTROLLING WATER SUPPLY TO SEPARATOR
VALVE CONTROLLING WATER SUPPLY TO OPEN SPRINKLERS IN SAW DUST BIN
BOILER FURNACE
FIRE HOSE CONNECTION
FLOOR LINE
PIPING AND FITTINGS TO BE SELECTED ASSEMBLED AND INSTALLED TO MEET CONDITIONS AND ARRANGED ACCORDING TO LOCATION
4" AUTOMATIC DRAIN VALVE - FOR SHUTTING OFF IN FREEZING WEATHER

WATER AND STEAM LINES IN FIRE PROTECTION PIPING FOR SHAVINGS BLOWER SYSTEM AND DUST COLLECTOR SEPARATOR. PIPE SIZES GIVEN FOR STEAMING ARRANGEMENT ARE FOR LOW PRESSURE STEAM. FOR HIGHER PRESSURES THESE SIZES CAN BE REDUCED

serious, and hard to extinguish. The separator, high on the roof, is not readily accessible and dragging a fire hose up the fire ladders to the roof at night, or in windy, stormy and cold weather is not pleasant. Furthermore, when the fire hose is in operation it is next to impossible to get the water where it will extinguish the fire, as the inside of the separator is a network of baffle plates and deflectors. The fire keeps on burning while all of this is going on and in some cases fire department men have remained for some time watching a smoldering and smoking separator to keep a fire from spreading to the remainder of the wood working plant.

In one case of a fire in one of these separators, a fireman opened the clean out door on the side of the separator and immediately the flames broke out, burning his arms and face badly.

The sketch herewith shows an arrangement of piping that was installed a few years ago in a boiler house of a plant that had a number of fires in its shavings and sawdust equipment and which has been in successful operation several times and been approved and well spoken of by the local fire department.

It consists of a pipe connection that will admit steam into the shavings pipe and also a pipe connection that will admit steam to the separator located on the roof of the building. Steam is one of the most effective fire extinguishers in a confined space or room. The steam pressure used in this case is seldom over 2 lb. Yet it will extinguish the fire when turned into this separator, which is of a large size, in less than a minute.

The controlling valves for these steam pipes should be arranged so that they can be quickly and conveniently opened from the floor and preferably from the outside of the building.

To provide for an occasion on which the boiler plant might be down and no steam available, a manually operated water connection from the underground fire lines was installed, one valve controlling a water supply to the top of the separator for flooding same and another valve controlling the water supply to some open sprinklers located overhead in the sawdust bin.

The arrangement and location of these water control valves will depend on the arrangement of the buildings and equipment. The valves should be installed so that they can be operated from either the inside or the outside of the building.

Plant managers in some cases say that a properly installed system of piping for the removal of shavings will not permit fire, and this may be true, but records will show that fires do happen to start in shavings pipes and sawdust storage. A steam pipe connection arranged for convenient operation is an effective way to protect against such danger and to stop a fire from following through a large shavings and sawdust transmission pipe leading from one building to another.

Enact Ordinance for Uniform Code

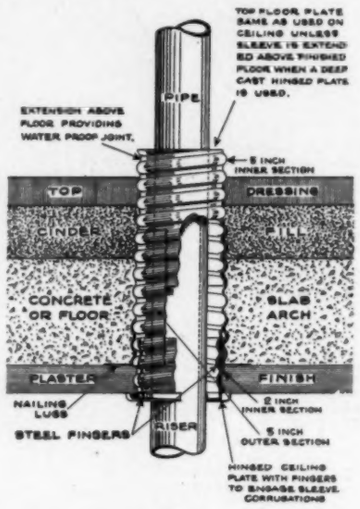
Fifty-three cities have now adopted the uniform building code of the Pacific Coast Building Officials' conference. The half-hundred mark was passed in less than 15 months after the first adoption by Pomona, Calif., on March 22, 1928. The fifty-third city passed the ordinance of adoption on May 21, 1929.

A New Type of Pipe Sleeve

The engineer and architect usually exercise extreme care in selecting the kind and grade of pipe that will best serve the particular purpose intended in the erection of a new building, but thought also should be given to protection of the pipe against external erosion where the pipe passes through masonry.

Pipe lines, especially risers at the point of passing through floors, have in some cases become so eroded as to cause breakage of lines and leakage. In many cases no protection whatever is given to the pipe in passing through masonry walls and floors, with the result that the acid in the concrete, especially of the cinder fill type, may rapidly eat away the pipe.

Pipe should not be installed through a masonry wall or floor without being fully protected by a pipe sleeve



of the best character obtainable. The sleeve should be placed in position at such time and in such manner as to avoid damage to the wall or floor masonry and so as to eliminate the necessity of "after-patching" which is expensive and often unsightly. The cutting of holes for pipes after the masonry is in place should always be avoided. It is damaging to the structure, expensive in repairs, and it is an unnecessarily expensive method of installing pipe lines and risers.

Similarly a properly made sleeve will prevent spawled and cracked plaster. In most cases it can be observed that the plaster is carried against the pipes and that the latter, in expanding and contracting, badly damage the plaster.

Such a sleeve must be rugged, to withstand the abuse to which it is invariably subjected during the building erection period, and it must be provided with substantial means of holding the sleeve firmly in its proper position.

To provide for varying wall and floor thicknesses it should be made telescopic by some simple means. It also must be of such form as to cause the concrete to adhere tightly to the exterior surface of the sleeve so as to make waterproof joint with the masonry, preventing damage to ceilings, walls or floors below when floors are mopped or when sprinkler heads open.

A sleeve designed to meet these requirements is illustrated here. It is made by the Knowles Pipe Sleeve Co., New York, N. Y.